

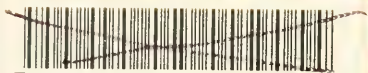


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STATE OF CONNECTICUT.

FIFTH ANNUAL REPORT

—OF THE—

STORRS SCHOOL

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1892.

Printed by order of the General Assembly.

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PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications should be addressed to

STORRS SCHOOL AGRICULTURAL
EXPERIMENT STATION,

STORRS, CONN.

Tolland County.

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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural School. The chemical and other more abstract work is carried out at Wesleyan University, Middletown.

16593.

OFFICERS OF THE STATION.

EXECUTIVE COMMITTEE.

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C. D. WOODS, Middletown,	-	-	-	-	-	-	<i>Vice-Director and Chemist.</i>
C. S. PHELPS, Storrs,	-	-	-	-	-	-	<i>Agriculturist.</i>
S. H. BUELL, Storrs,	-	-	-	-	-	-	<i>Assistant in Farm Experiments.</i>

Report of the Executive Committee.



To His Excellency Luzon B. Morris,

Governor of Connecticut :

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly, approved March 6th, 1889, relating to the publication of Reports of the Storrs School Agricultural Experiment Station, we have the honor to present herewith the Fifth Annual Report of that Station, namely, that for the year 1892.

The Director, Prof. W. O. Atwater, has been in Europe a part of the year. In his absence the Vice-Director, Charles D. Woods, has had the charge of the work of the Station, and has been responsible for the details of its operations.

The following changes in the Station staff have been made during the year: Mr. E. A. Bailey, Assistant Agriculturist, and Mr. H. M. Smith resigned their positions July 1st, and at the same time Mr. S. H. Buell was appointed Assistant in Farm Experiments.

The Committee refer to the accompanying report of the Treasurer for details of expenditure, and to that of the Director and his associates for the history of the work accomplished, and express their confident belief that the funds have been wisely expended and the work such as will result in great benefit to our agricultural interests.

Respectfully submitted,

T. S. GOLD,	} <i>Executive</i>
J. M. HUBBARD,	
B. F. KOONS,	

Committee.

Apparatus, permanent,	-	-	-	-	-	-	-	-	-	\$335 74
Chemicals,	-	-	-	-	-	-	-	-	-	120 67
Coal, gas and oil,	-	-	-	-	-	-	-	-	-	217 97
Hardware and lumber,	-	-	-	-	-	-	-	-	-	39 51
Freight, cartage and express,	-	-	-	-	-	-	-	-	-	46 98
Bacteriological investigations,	-	-	-	-	-	-	-	-	-	112 08
Office furniture,	-	-	-	-	-	-	-	-	-	12 50
Incidentals,	-	-	-	-	-	-	-	-	-	38 84
Balance in treasury,	-	-	-	-	-	-	-	-	-	130 55

\$7,857 34

HENRY C. MILES,

Treasurer.

This will certify that we have examined the accounts of Henry C. Miles, Treasurer of the Storrs School Agricultural Experiment Station, for the fiscal year ending June 30, 1892, compared the vouchers therewith and find the same correct, showing a balance in said Treasurer's hands at the close of said fiscal year amounting to \$130.55.

D. WARD NORTHROP, } *Auditors of*
 BENJAMIN P. MEAD, } *Public Accounts.*

MILFORD, CONN., December 24, 1892.

Report of the Director.

The lines of experimental work in which this Station has been engaged during the past year are, for the most part, in continuation of those previously begun. They have been as follows:

1. Co-operative field experiments with fertilizers by the Station and by farmers on their own farms in different parts of the State. These experiments are the same in character and scope as those of previous years.
2. Observations on the growth of grass and forage plants at the Station and elsewhere, with especial reference to the cultivation of legumes.
3. Experiments upon the acquisition of atmospheric nitrogen by growing plants.
4. Meteorological observations at the Station throughout the year, and observations of the rainfall in connection with the field experiments in different parts of the State during the growing season.
5. Experimental studies of the bacteria of milk and their action.
6. Feeding experiments with milch cows.
7. Investigations of dietaries and studies of the chemical composition of the food of man. The studies of dietaries have been made in connection with the U. S. Department of Labor.
8. Investigations with the calorimeter upon the heats of combustion of materials used as food for domestic animals and man.
9. Preliminary experiments in the elaborating of a calorimetric respiration apparatus.

My duties in connection with the Office of Experiment Stations of the Department of Agriculture at Washington and in Europe, have been such that for a considerable part of the past year I have been able to exercise only a general supervision of the work of the Station. It would be wrong to omit an expression of appreciation of the efficient manner in which the Vice-Director, Mr. Charles D. Woods, has, during my absence, performed the duties of Acting Director. I desire also to bear witness to the ability and faithfulness with which all of the gentlemen associated with me have executed the work intrusted to them.

SUMMARY OF THE PRESENT REPORT.

THE ASSIMILATION OF THE FREE NITROGEN OF THE AIR BY PLANTS.

PAGES 17-22.

In accounts of investigations reported by the writer in 1881-5, in which peas were shown to acquire large quantities of nitrogen from the air, it was urged that the fixation of free nitrogen, though not absolutely proven, was extremely probable. Later researches by Hellriegel, Lawes and Gilbert, and others in Europe, and by this Station, have confirmed the assimilation of free nitrogen. A series of experiments was devised for the purpose of inquiring into the ways by which the plants acquire the nitrogen, but circumstances have thus far prevented their being carried out, and only the preliminary trials have been made. In these trials pea plants were grown without access to combined nitrogen either in the air or the soil (sand) or the fertilizing materials or otherwise, except the very minute quantity in the soil infusions with which the roots were inoculated and of course, that in the seed. The plants when mature showed a considerable gain of nitrogen, which must have come from the free nitrogen of the air.

ANALYSES OF FODDERS AND FEEDING STUFFS.—PAGES 23-35.

Analyses of about 150 specimens of miscellaneous feeding stuffs, mostly grasses and other forage plants, field-cured grains and some milling products, have been made during the year by the Station chemists, in connection with feeding experiments or experiments upon the growth of plants. In no case were the analyses undertaken merely to increase the number of data of this class, though they are of course valuable for that purpose.

SPECIAL NITROGEN EXPERIMENT ON GRASS.—PAGES 36-46.

The object of this experiment is to study the effect of nitrogenous fertilizers upon grass, as shown by the yield per acre, the chemical composition of the hay, and the financial results. The plan consists in applying different fertilizers to parallel plots of land, and weighing and analyzing the produce. The experiment has been continued through several successive years, with the

same fertilizers on the same plots. The plots contained one-eighth acre each, and were separated from each other by unfertilized strips. Mineral fertilizers, supplying phosphoric acid and potash, were applied to all the plots except one, which was left unmanured, and, with one exception, nitrogen was applied to the manured plots at the rate of 25, 50, and 75 pounds per acre. The results are summarized by Messrs. Woods and Phelps as follows:

The addition of mineral fertilizers increased the yield of clover, but did not seem to increase very materially the yield of grasses. In general the yield of hay increased with the quantity of nitrogen supplied. The mineral fertilizers when used alone were applied at a financial loss. The application of 160 pounds of nitrate of soda per acre (25 lbs. of nitrogen), in addition to the mixed minerals, gave an average profit during the three years of \$1.40 per acre; 320 pounds of nitrate of soda (50 lbs. of nitrogen) gave an average profit of \$5.24 per acre, and 480 pounds of nitrate of soda (75 lbs. of nitrogen) an average profit of \$2.45 per acre. The returns from 320 pounds were very uniform, the profit being \$5.10, \$5.12 and \$5.49 respectively for the three years. The application of nitrogenous fertilizers increased the percentages of protein in the crop and somewhat in proportion to the amount of nitrogen supplied. The increase in the amount of nitrogen in the crop did not equal the increased amount of nitrogen supplied in the fertilizers, thus implying that the plants were not able to utilize all the nitrogen supplied.

EFFECTS OF DIFFERENT FERTILIZERS UPON THE COMPOSITION OF
OATS AND STRAW.—PAGES 47-56.

This work, which is in continuance of an investigation described in the Annual Report of the Station for 1890, was undertaken with the hope of getting more light upon the effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of the grain and straw of the oat plant, with special reference to the effect of nitrogenous fertilizers upon the amounts of protein. The plan is similar to that of the experiments on grass just referred to. The results are stated by Mr. Woods as follows:

The crops from two special nitrogen experiments with oats and one soil test experiment with oats have been analyzed. The percentage of protein increased in both oats and straw with the

application of nitrogen in the form of nitrate of soda or sulphate of ammonia, and this increase was somewhat in proportion to the amounts applied. In the experiment of 1890 the use of different amounts of dried blood in the fertilizer did not materially affect the percentages of protein in either the oats or the straw. In 1892 there was an increase in the protein from the use of the largest amount (75 pounds nitrogen per acre) of dried blood. There was an increase in pounds of protein per acre in the plots supplied with nitrogenous fertilizers, somewhat in proportion to the amounts applied. This increase was greatest in the plots on which nitrate of soda was used. These results are in accord with observations made by the Station upon the relation of the protein in corn, and in grass, to the nitrogen applied in the fertilizers.

EFFECT OF NITROGENOUS FERTILIZERS UPON THE PERCENTAGES OF PROTEIN IN GRASSES AND GRAINS.—PAGES 60-66.

The outcome of 73 field experiments, during several years past, upon the effect of nitrogenous fertilizers upon the protein of the crop, are concisely summed up by Mr. Woods, as follows:—

Results of Analyses showing Relation between Nitrogen applied in Fertilizers and Protein found in Resulting Crops.

KIND OF CROP.	No. of Experiments.	Phosphoric Acid and Potash (Mixed Minerals).	Mixed Minerals and 25 lbs. Nitrogen per acre.	Mixed Minerals and 50 lbs. Nitrogen per acre.	Mixed Minerals and 75 lbs. Nitrogen per acre.
		%	%	%	%
Corn (grain), - - - -	22	10.9	11.3	11.4	12.1
Oats (grain), - - - -	5	15.1	15.4	15.7	16.3
Corn stover, - - - -	22	6.2	6.6	6.6	7.6
Oat straw, - - - -	5	5.3	4.7	5.2	6.0
Mixed grasses, - - - -	5	7.6	7.6	8.8	9.8
Orchard grass, - - - -	2	8.9	10.2	—	12.6
Timothy, - - - -	2	7.7	8.1	—	10.6
Red-top, - - - -	3	—	8.3	—	11.7
Seven other pure grasses, -	7	—	10.2	—	12.1

The results as shown in the table need no explanation, as the figures tell the story so plainly. In general, the percentages of protein increased with the amount of nitrogen applied, though,

in most cases, the application of the largest amount of nitrogen seemed to have the most marked effect upon the protein of the crop.

PRACTICAL CONCLUSIONS REGARDING NITROGENOUS FERTILIZERS
AND FEEDING STUFFS.

The Station has for years been urging upon the attention of farmers the value of nitrogenous feeding stuffs. The progress of exact experiment is bringing out the desirability of such materials more and more clearly. Thus the experiments on the effects of fodder upon the production of milk and meat lately made in Experiment Stations in the United States and in Europe, emphasize most forcibly the need of rations much richer in protein than most of our farmers feed.

Our crops contain a large excess of the materials which serve as fuel, while the protein compounds, which make muscle, bone, and milk, are relatively wanting. The farmer is primarily responsible for this state of affairs, and must be the one to take the first steps to amend it. The protein needed for the use of the stock kept on the farm may be obtained in one of three ways: It may be purchased in the form of concentrated feeds, such as wheat bran, oil meals, etc.; it may be obtained by growing the legumes which are able to obtain nitrogen directly from the air and convert it into protein; or it may be obtained by breeding and importing varieties of grains and grasses richer in nitrogen than those now cultivated. While it is probable that the feeder must, for the present, continue to buy some of the protein which his animals need, still by care in selection of crops, and by growing plants richer in nitrogen, much more protein may be produced on the farm itself. This protein is needed for fodder in order to make leaner meat, and more of it, and more milk at less cost. The nitrogen not transformed into meat or milk makes rich manure for grasses, grains, and other crops, and the rich manure helps to bring larger crops, and crops richer in protein.

RESULTS OF EXPERIMENTS WITH FERTILIZERS ON DIFFERENT
CLASSES OF SOILS.—PAGES 67-84.

The reports of about 90 soil test experiments with fertilizers, conducted in this and other New England States during the past 15 years, on plans suggested by the writer, have been studied by Prof. Phelps with reference to the classes of soils, for the purpose of ascertaining the relations, if any, between the kinds of

soils and their deficiencies. The results have been summarized in two groups: (1) soils ranging from sandy to loam, and (2) soils ranging from heavy loam to heavy clay. The teachings of the experiments thus far made in Connecticut imply that for soils in this state generally, though of course there may be exceptions:

Nitrogen.—This is more apt to be beneficial on the light than on heavy soils. Soluble fertilizers, as nitrate of soda and sulphate of ammonia, can generally be used with profit on light loam soils, but do not prove of much value for corn on heavy soils. For heavy soils nitrogen should be supplied in some organic form, as stable manure, dried blood, etc.

Phosphoric Acid and Potash.—Heavy, clayey soils need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light, sandy to loam soils are more generally, though not uniformly, helped by potash fertilizers.

The wide differences found in soils afford a strong argument in favor of home mixed fertilizers. The special needs of different soils cannot be considered by the manufacturer who prepares his fertilizers for general use. The farmer may, however, prepare such mixtures as will meet both the deficiencies of his soil and the requirements of his crops.

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.—PAGES
85-105.

The Station has continued its coöperative field experiments through a fifth year, the plan being similar to that of former years. Seven "soil test" experiments upon corn and one "soil test" and one "special nitrogen" experiment with oats have been made by farmers in different parts of the State during the past year, and are reported upon by Prof. Phelps.

BACTERIA IN THE DAIRY.—PAGES 106-126.

Prof. Conn has continued his investigations, in connection with the Station, upon bacteria in the dairy and in the present Report gives a paper upon *The Isolation of Rennet from Bacteria Cultures*. He describes in detail the experiments and the species of bacteria studied. His conclusions are as follows:

Many species of bacteria that have the power of liquefying gelatine, produce, as a result of their growth in milk, a certain quantity of an enzyme which, so far as can be at present determined, has all of the essential characteristics of rennet. This

rennet can be isolated from bacteria cultures by filtering the cultures through a porcelain cylinder and then treating the filtrate with alcohol. A better method, which gives the rennet in a purer condition, though by no means pure, is to precipitate it from its solution by an excess of salt instead of alcohol. It has been found possible to isolate this rennet from milk in the case of all species of bacteria thus far studied which curdle the milk without rendering it acid. Different species of bacteria differ very much in the amount of rennet which they produce and the rapidity with which they produce it. Several species of bacteria have been found to produce rennet in considerable quantity, even where they are not capable of curdling the milk. The explanation of the fact is that the production of a tryptic ferment obscures the production of the rennet ferment in these cases, and the casein becomes peptonized before it can be precipitated by the more slowly forming rennet. The organisms experimented upon seemed in every case to produce a larger amount of rennet when growing at a moderately low temperature than when growing at a temperature of 35° C. The rennet isolated in this way has all of the general reactions of dairy rennet, and is subject to destruction by high temperatures in a similar manner.

A STUDY OF ACTUAL DIETARIES.—PAGES 135-162.

During the year the Station has studied the dietaries of families of a jeweler, a blacksmith, a machinist, a mason, and two carpenters. The results are given in detail and a summary of the results of these and the two other dietaries previously examined is appended in the account of the work by Mr. Woods.

ECONOMY OF FOOD.—PAGES 163-190.

The cost of food is the principal item of the living expenses of the majority of the people—of all, indeed, but the especially well-to-do. Wage-workers and people of moderate incomes generally in Connecticut and the Eastern States spend and must spend over half their earnings for food. Although the cost of food is so great, and although the health and strength of all are so dependent upon their diet, yet even the most intelligent people know very little about the actual uses and values of their food for fulfilling its purposes. The result is great waste in the purchase and use of food, loss of money, and injury to health.

The last Annual Report of this Station gave accounts of chemical analyses of a considerable number of our common food materials; results of studies of the kinds, amounts and composition of the food actually eaten in families and boarding houses in New England; and some comparisons between these dietaries and those of people in corresponding circumstances in Europe. The present report describes further studies and discusses the chemical composition, digestibility, and nutritive values and pecuniary economy of foods.

Examinations of Dietaries.—An important part of the inquiry is the examination of the food purchased and used by people, mostly wage-workers, which has been undertaken in connection with the United States Department of Labor. The method consists simply in making arrangements with families and boarding houses, by which not only all food purchased but the unconsumed portions also, the kitchen and table wastes, are weighed and specimens taken for analysis. At the same time account is kept of the number of persons at the table and the number of meals eaten by each. In this way it is possible to learn exactly the kinds and proportions of actual nutrients eaten and compare them with those required by physiological standards. The same investigations show, of course, just how the nutritive material consumed compares with the cost, and in how far the food is economically or wastefully used.

Home Studies of Dietaries.—Efforts are being made to aid intelligent private families to make studies themselves of their food consumption. The results thus far are decidedly encouraging.

Mistakes in our Food Economy.—The studies thus far made point to four errors in our food economy: We buy needlessly expensive kinds of food; many of us use more than we need; that which we consume is very apt not to contain the different nutritive ingredients in the proportions best adapted to our needs for nourishment, we use an excess of meats and sweetmeats; and, finally, we throw away a great deal of food that ought to be utilized.

Cheap vs. Dear Food.—The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time best adapted to the wants of the user. The maxim that "the best is the cheapest" does not apply to food. The best food in the sense

of that which is the finest in appearance and flavor and which is sold at the highest price, is not generally the cheapest, nor is it always the most healthful or economical.

A quarter of a dollar invested in the sirloin of beef at 22 cents per pound pays for one and one-seventh pounds of the meat with three-eighths of a pound of actually nutritive material. This would contain one-sixth of a pound of protein to make blood and muscle, and one-fifth of a pound of fat, and supply 1,120 Calories of energy, *i. e.*, heat to keep the body warm and muscular power for work. The same amount of money paid for oysters, at the rate of 50 cents per quart, brings two ounces of actual nutrients, an ounce of protein, and 230 Calories of energy. But in buying wheat flour at seven dollars a barrel, the 25 cents pay for six and a quarter pounds of nutrients, with eight-tenths of a pound of protein and 11,755 Calories of energy.

Waste of Food.—We waste food in two ways. We eat more than we need, and a great deal is simply thrown away. That which is rejected in kitchen and table refuse does no harm, but that which we consume in excess of our needs is worse than wasted, because of the injury it does to health. In some of the dietaries examined from one-ninth to one-twelfth of the nutritive material was simply thrown away, and, what made the matter still worse from the pecuniary standpoint, the portions thus rejected were mostly from the meats, in which the nutritive ingredients are the most costly.

Food of the Poor.—The saddest part of the whole story is that it is the poor man's money that is the most uneconomically spent in the market, and the poor man's food that is worst cooked and served at home. Indeed it is as surprising as it is pathetic to see how much people of limited incomes lose in this way. Here it is true that "To him that hath shall be given, and from him that hath not shall be taken away even that which he hath."

What Needs to be Done?—The first step toward dietary reform is the getting of a better understanding of the facts; the next, the diffusing of these among the people. What has been reported by the Station is of course only a beginning and a very small one in this direction, but it is hoped that it may not be without usefulness.

W. O. ATWATER,
Director.

THE FIXATION OF FREE NITROGEN BY PLANTS.

BY W. O. ATWATER AND CHAS. D. WOODS.



In the Annual Report of this Station for 1890* reference was made to plans then in contemplation for experiments upon the fixation of nitrogen by plants. In accounts of investigations reported by one of us (W. O. A.) in 1881-85, in which peas were shown to acquire large quantities of nitrogen from the air, it was urged that the acquisition of free nitrogen, though not absolutely proven, was extremely probable. Researches since then by Hellriegel and Wilfarth, Wolff, Breal, Lawes and Gilbert, Frank, Schloessing and Laurent, Petermann, and others, including the writers, have placed the fixation of free nitrogen of the air by plants beyond doubt, and have shown that micro-organisms are in some way connected with the process.† The especial purpose of the experiments here contemplated was the study of the ways by which the nitrogen is obtained through either the roots or the foliage or both. Circumstances have thus far prevented the carrying out of the inquiry with the details proposed, and only a series of preliminary trials on the growth of plants in an atmosphere freed from compounds of nitrogen has been completed. While the results prove nothing essentially new, they are worth reporting in brief as confirmatory evidence of the fixation of the uncombined nitrogen of the air.

PLAN OF EXPERIMENTS.

It was desired to grow the plants under conditions as nearly normal as possible, but with entire exclusion of nitrogen compounds from both the air and the medium containing the roots. For this purpose a glass case was so constructed as to insure

* Page 12.

† See *Am. Chem. Journal* VI., sec. 68; VIII., 368; Annual Reports of this Station for 1889, p. 11; 1890, p. 12, and 1891, p. 17, and review of history of the subject with especial references to the relations of root tubercles to the acquisition of nitrogen in Experiment Station Record, III., p. 56.

air-tight closure and yet afford convenient access to the plants from time to time. It was, indeed, in principle and in appearance a large Wardian case, and was located in a greenhouse. A stream of air carefully washed by water, alkali, and acid, was caused to flow through the case. Carbon dioxide was added each day in quantities judged to be sufficient for the needs of the plants. The whole apparatus was inside of a greenhouse whose temperature could be fairly well regulated. Pea plants were used for the experiment, as we had better success with them than with other legumes in our previous experience. They were grown in purified sea sand, supplied with nutritive solutions, inoculated with soil extract, and, with the exception of the watering as stated beyond, were treated as were those of the experiments previously described.* Considerable difficulty was found in maintaining the temperature of the case at low enough point for the healthy development of pea plants. A series of experiments undertaken in the spring months gave rather poor growth, presumably from the high temperature in the sunshine. To obviate this, another series, which is here reported upon, was undertaken late enough in the fall, so that by thoroughly ventilating the greenhouse, the temperature inside the case could be kept within reasonable limits.

DETAILS OF EXPERIMENTS.

The case was constructed of wood and glass; it was 6 feet in length, $4\frac{1}{2}$ feet in width, and 4 feet in height. The joints were carefully made, and the glass was bedded and laid with white lead putty. It had no bottom. The platform on which it rested and by which it was closed was covered with sheet lead. The four sides of the case had on the lowest edge a square tongue, one inch thick and one inch deep, which projected into a corresponding groove or channel in the platform, so that when the channel was filled with an appropriate liquid as water or mercury or glycerine—the last was actually used—connection between the atmosphere within and without the case was efficiently cut off. Ropes and a pulley above made it easy to raise and lower the case as occasion demanded.

Circulation of Air.—A current of purified air was forced through the case with the aid of a pump such as is used in the manufacture of gasoline gas. The air passed through a meter by which the

* Reports of this Station, 1889, pp. 11-51; 1890, pp. 12-14; 1891, pp. 17-28.

volume was measured and the rate of flow was regulated accordingly. The quantity passed through per day was about equal to the volume contained in the case, *i. e.*, not far from 100 cubic feet.

Purification of Air.—Between the pump and the case the air was passed through a solution of sodium carbonate to absorb the nitric and nitrous acids, and then through a solution of sulphuric acid to free it from ammonia. The washing solutions were in carboys of about 18 liters capacity, so that the air was in contact with them for a much longer time than while merely bubbling through the solutions. The pump itself was so constructed that all of the air introduced had to pass through water. This insured the washing out of atmospheric dust and of a large part of the ammoniacal salts, nitrites, and nitrates. In cases in which the test was made, it was not until 75 or 100 cubic feet of air had passed through the pump that it began to give a perceptible color in passing through a solution containing Nessler's reagent. Only a part of the nitrogen compounds had to be removed by the alkaline and acid solutions in the carboys. The gases thus washed were tested from time to time by passing through a solution containing Nessler's reagent. In no instance was ammonia detected, although the periods of flow of the air through the solution were of considerable length.

The presence or absence of ammonia was further tested by keeping sulphuric acid in an open vessel within the case throughout the whole period of the experiment. At the beginning 15 cc. of strong sulphuric acid were placed in a flat bottomed porcelain dish having a diameter of about 11 cm. At the end of the experiment the acid solution had increased in volume by absorption of water to about 250 cc. This was rendered alkaline by the addition of sodium hydroxide, which was free from ammonia, and was then tested with Nessler's reagent. There was the faintest possible coloration, but the amount of ammonia was too slight for estimation. The same amount, 15 cc., of fresh strong sulphuric acid was diluted to like volume with ammonia-free water and then neutralized as above. This gave as much color with Nessler's reagent as did that which had been in the case for 85 days. It thus seems reasonable to conclude that there was at no time any considerable amount of ammonia in the atmosphere within the case.

It was assumed that washing the air in both water and alkali solution freed it completely from nitric and nitrous acids.

Supply of Carbon Dioxide.—By a convenient arrangement carbon dioxide was introduced into the case each day in such quantity as was deemed desirable for the proper growth of the plants. In general the atmosphere within the case contained from three to six times as much carbon dioxide as ordinary air.

Pots. Sand.—The plants were grown in glass jars, placed in boxes, similar to those described in earlier reports. They contained sea sand, which had been carefully washed and ignited so as to reveal no trace of nitrogen compounds when tested by either the soda lime or the Kjeldahl method.

Nutritive solutions. Planting. Inoculation—The nutritive solutions were all made with specially prepared, "nitrogen-free" water, *i. e.*, water which had been distilled with alkali, and potassium permanganate, and gave no appreciable reaction for ammonia with Nessler's reagent. They supplied the plants with the needed mineral constituents, but included no compounds of nitrogen. The seeds were planted before germination. At time of planting the nutritive solutions were applied and "nitrogen-free" water was added in sufficient amount to moisten all of the sand in the jar. In order to insure inoculation with the organisms which produce root tubercles, 25 cc. of infusion prepared from soil in which pea plants developing large numbers of root tubercles had been grown, were added at two periods, once at the time of planting the seeds and again when the plants were in the third leaf.

Watering.—The atmosphere of the case was saturated with moisture to such an extent that although the experiment continued for nearly three months, the soil in which the plants grew never became sufficiently dry to seem to need additional supplies of water. Accordingly, the water added at the beginning of the experiment was all that was supplied the plants. The pots, sand, "nitrogen-free" water, soil infusion, and the methods of their preparation and use are described in the account of previous experiments.*

RESULTS OF EXPERIMENTS.

Under such circumstances as these in which the plants were placed, their development was as nearly normal as could be expected. The height was generally as great as is usual with dwarf peas, but the yield of seed was small.

*Report of this Station, 1889, pp. 16-20.

The table (1) herewith gives the principal statistics of the experiments.

TABLE I.

Pea Plants Grown in Sand in Glass Jars—No Compounds of Nitrogen in Air, Soil, or Nutritive Solutions.

Reference Numbers.	Height.	No. of Peas.		Root Development.	Tubercle Development.	Weight of Mature Plants (air dry).			Nitrogen Statistics.		
		Mature.	Immature.			Tops.	Roots.	Total.	Nitrogen in Seed.	Nitrogen in Plant at end of exp't.	Gain of Nitrogen.
566, -	27	1	2	Poor.	Fair.	500	290	790	10	16	6
567, -	43		3	Fair.	Good.	760	470	1230	10	30	20
568, -	32	2	1	Good.	Fair.	560	480	1040	10	18	8
569, -	30	3		Good.	Fair.	770	640	1410	10	25	15
571, -	21	1	1	Poor.	Good.	400	230	630	10	11	1
572, -	37	2		Good.	Few.	570	370	940	10	15	5
573, -	30	1	2	Poor.	Few.	500	270	770	10	16	6
574, -	34	3		Fair.	Fair.	820	420	1240	10	22	12
575, -	24	1		Fair.	Very few.	490	290	780	10	14	4
576, -	27	2	1	Fair.	Fair.	600	260	860	10	20	10
577, -	29			Good.	Very few.	420	530	950	10	12	2
578, -	23	2		Good.	Few.	470	400	870	10	16	6
579, -	34	1	1	Fair.	Very few.	590	720	1310	10	16	6
580, -	29	2		Good.	Good.	700	260	960	10	22	12
581, -	31	2		Good.	Good.	710	450	1160	10	20	10
582, -	32	2	1	Fair.	Fair.	960	590	1550	10	29	19
583, -	29	2		Fair.	Good.	630	130	760	10	19	9
584, -	27	1	1	Good.	Few.	440	200	640	10	12	2
585, -	29	2		Fair.	Good.	670	240	910	10	20	10
586, -	31	2	1	Good.	Good.	660	450	1110	10	21	11
587, -	25	2		Good.	Fair.	470	140	610	10	13	3
588, -	28	2	2	Good.	Good.	720	150	870	10	23	13
589, -	33	2	1	Good.	Good.	850	100	950	10	27	17
590, -	30	3	2	Good.	Fair.	950	570	1520	10	25	15
591, -	26	2		Poor.	Fair.	520	200	720	10	16	6
592, -	28	2		Good.	Good.	630	240	870	10	18	8
593, -	30	2		Fair.	Fair.	530	260	790	10	16	6

The root development was designated "poor," "fair," or "good," according to the amount of roots found at the end of the experiment. The number of root tubercles is spoken of as "very few," "few," "fair," or "good," in accordance with their abundance as compared with the amount of roots. What would be a "fair" or even a "good" development of root tubercles with

"poor" roots might be classified as "few" with "good" roots. Hence, in judging of the tubercle development as indicated in the table, it is necessary to consider the root development as well as that of the tubercles themselves. Of course, such a classification is indefinite and entirely arbitrary, but it serves to express the estimates as roughly made.

The last three columns of the table contain the nitrogen statistics. It will be observed that in every case there was a gain of nitrogen, though in several instances this gain is slight. The total gain by the twenty-seven plants growing in the case was about one-fourth of a gram; an average of nine milligrams per plant. The largest gains were generally in the instances where either the root development and that of the tubercles were both "good," or else one was "good" and the other was "fair." In other words, the gain of nitrogen was larger or smaller as the tubercles were well or poorly developed.

The results of these experiments confirm those of the earlier ones here, and at the same time justify the assumption which we had previously made that the increase of nitrogen found in the plants was due not so much to compounds of nitrogen in the atmosphere as to the fact that the plants acquired the free nitrogen of the air. Whether the plants are entirely dependent upon their roots for this acquisition from the air or whether a part at least may be obtained through their foliage is a question not yet settled. It is hoped that the pressure of other work may be in so far removed as to permit in the not distant future the carrying out of plans which have been matured for the study of this and collateral questions.

SUMMARY.

Pea plants were grown in an atmosphere freed from all nitrogen compounds. The nutritive solutions supplied all necessary mineral constituents. Carbon dioxide was added as needed. No compounds of nitrogen were supplied either in the air, soil or nutritive solution. The plants were inoculated with soil infusions, and all developed root tubercles. The twenty-seven plants made a total gain of about one-fourth a gram of nitrogen, or an average gain of nine milligrams per plant. The free nitrogen of the air was alone available to the plants, and the gain must have been by the acquisition of free nitrogen.

RESULTS OF ANALYSES OF FODDERS AND FEEDING STUFFS.

BY CHAS. D. WOODS.

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In connection with the work of the Station, analyses of the following miscellaneous feeding stuffs have been made by the Station chemists. For the most part the analyses were made in connection with feeding experiments or experiments upon the growth of plants, and were in no case undertaken merely to increase the amount of this class of data. The methods of analysis recommended by the Association of Agricultural Chemists were employed.

The results of the analyses calculated to water content at harvest or at the time of analysis are given in table 2, page 28, which follows the description of samples. In this table the materials are grouped according to their water content at time of taking samples as follows: Green fodders; roots and ensilage; field cured hay, fodder and straw; cured hay and fodder; grain; and milling products. This order is also observed in the description of samples.

The results calculated to water-free (dry matter) basis are given in table 3, page 32. In this table the different species and varieties are grouped together regardless of their moisture condition at time of sampling in the following order: Grasses, straw, legumes, grain, and milling products.

The potential energy, or fuel value, of a pound of each of the feeding stuffs as given in the tables was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6 and the number of hundredths of a pound of fat by 42.2 and taking the sum of these three products as the number of Calories of potential energy in the materials.*

DESCRIPTION OF SAMPLES.

In the description of samples the specimens are arranged in the same order as in table 2, as follows:—Green fodders; roots and ensilage; field cured hay, fodder and straw; cured hay and fodder; grain, and milling products.

*See article on the Fuel Value of Feeding Stuffs, Report of this Station, 1890, pp. 174 to 181.

GREEN FODDERS.

1000 to 1003, *Orchard Grass* (*Dactylis glomerata*).—Grown by the Station in 1891. At the time of taking samples the seeds were just beginning to form. No. 1001 was from a plot without fertilizers. No. 1000 was from a plot supplied with dissolved bone-black at the rate of 320 pounds per acre and with muriate of potash at the rate of 160 pounds. No. 1002 was from a plot which, in addition to the minerals of 1000, had nitrate of soda at the rate of 160 pounds per acre. No. 1003 was from a plot which, in addition to the minerals of 1000, received nitrate of soda at the rate of 480 pounds per acre.

1004 to 1007, *Timothy* (*Phleum pratense*).—Grown by the Station in 1891. At time of taking sample the timothy was just beginning to bloom. No. 1005 was grown without the use of fertilizers. No. 1004 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1006 was from a plot which had the same mineral fertilizers as 1004 and, in addition, received nitrate of soda at the rate of 160 pounds per acre. No. 1007 was grown on a plot to which mixed minerals were applied as in 1004 and had, in addition, 480 pounds of nitrate of soda per acre.

1024 and 1025, *Hungarian Grass* (*Setaria Italica*).—Grown by the Station in 1891. No. 1024 was taken while in early bloom and contained a few weeds. No. 1025 was past full bloom when the sample was taken. The crop was affected by drouth and did not seem to have made a normal growth.

1072, *Hungarian Grass* (*Setaria Italica*).—Grown by the Station in 1892. The grass was a little past full bloom and seed was beginning to form when the sample was taken.

1015, *Wheat Fodder*.—Grown by the Station in 1891. At time of cutting it was three feet tall and in bloom. The yield was light.

1052 and 1053, *Wheat Fodder*.—Grown by the Station in 1892. No. 1052 had heads one-third to one-half grown. No. 1053 was in bloom and had made a heavy growth.

1023, *Red Clover* (*Trifolium pratense*).—Clover rowen grown by the Station in 1891. It included a little timothy. At time of cutting the clover was in bloom and beginning to form seed.

1028, *Red Clover* (*Trifolium pratense*).—Clover rowen grown in 1891 and consisted approximately of about one-fourth timothy and three-fourths clover. At time of cutting the clover was in early bloom; the timothy showed a few heads.

1112, *Red Clover* (*Trifolium pratense*).—Clover rowen grown in 1892. At time of taking sample it was past full bloom and seed was beginning to form.

1113, *Scarlet Clover* (*Trifolium incarnatum*).—Grown by the Station in 1892. It was sown early in the spring. The sample was taken at the beginning of October, at which time it was generally seeded, but was still growing vigorously by sending up shoots from below. The sample contained a few weeds.

1022, *Cow Pea* (*Dolichos sinensis*).—Grown by the Station in 1891. The peas were generally in bloom and a few imperfectly developed pods and seeds had formed.

1114, *Cow Pea* (*Dolichos sinensis*).—Grown by the Station in 1892. At time of taking sample the peas were about fully grown, but were not seeded.

1014, *Oat and Pea Fodder*.—Grown by the Station in 1891 on land fertilized with stable manure. At time of taking sample the oats were in bloom; a few beginning to seed.

1070 and 1071, *Oat and Pea Fodder*.—Grown by the Station in 1892. The peas in each case had formed a few seeds; the oats were in full bloom.

1026, *Oat and Vetch Fodder*.—Grown by the Station in 1891 on land that was fertilized with stable manure. At time of taking the sample the oats were beginning to form seed; the vetch was in bloom.

1029, *Barley and Pea Fodder*.—Grown by the Station in 1891. Sample was taken October 25, at which time the barley was generally headed. The peas were in early bloom. Owing to the warm, dry fall, neither the barley nor the peas appeared to make a normal growth, and the yield was light.

ROOTS AND ENSILAGE.

963, *Mangolds*.—Grown in Connecticut in 1890. Analyzed in January, 1891.

966, *Corn Ensilage*.—The ensilage was quite acid, 100 grams containing free acid equal to 125 milligrams ammonia.

FIELD CURED HAY AND FODDERS.

1017 to 1020, *Corn Stover*.—Grown by the Station in 1891 with different fertilizers. No. 1017 was grown without the use of fertilizers. No. 1018 was from a plot to which dissolved bone-black was applied at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1019 was from a plot which had the same mineral fertilizers as 1018 and in addition received nitrate of soda at the rate of 160 pounds per acre. No. 1020 was grown on a plot to which mixed minerals were applied as in 1018, and had in addition 480 pounds of nitrate of soda per acre.

1097 to 1108, *Oat Straw*.—From special nitrogen experiment conducted by the Station at Wapping in 1892. Nos. 1097 and 1098 were grown without the use of fertilizers. Nos. 1099, 1100, 1101, and 1102 were grown upon plots to which there were applied dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds. Nos. 1103, 1104, and 1105 were from plots grown with the same mineral fertilizers as the preceding, but had in addition 160, 320 and 480 pounds of nitrate of soda per acre respectively. Nos. 1106, 1107, and 1108 were grown upon plots to which were applied the mixed minerals, and in addition dried blood at the rate of 200, 400 and 600 pounds per acre respectively.

990 to 999, *Hay from Mixed Grasses*.—Grown by the Station in a special nitrogen experiment in 1891. Nos. 990 and 991 were grown without the use of fertilizers. Nos. 992 and 993 were grown upon plots to which were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. The crop from these plots contained a larger percentage of clover than did the others. Nos. 994, 995 and 996 were grown upon plots to which was applied in addition to the mixed minerals of the preceding, nitrate of soda at the rate of 160, 320 and 480 pounds per acre. Nos. 997, 998 and 999 were grown upon plots which had in addition to the mixed minerals, sulphate of ammonia at the rate of 120, 240 and 360 pounds per acre respectively.

1054 to 1059, *Hay from Mixed Grasses*.—Grown by the Station in 1892, and were from the same experimental field as the above samples, which were grown

in 1891. No. 1054 was from the same plot as 990 above, 1055 from the same plot as 992, 1056 from the same plot as 994, 1057 from the same plot as 995, and 1058 from the same plot as 996. The plots had the same treatment as in 1891. No. 1059 was from the same plot as 1055, but was carefully selected so as not to contain any clover.

CURED HAY AND FODDERS.

1044 to 1047, *Orchard Grass* (*Dactylis glomerata*).—Grown by the Station in 1892 and from the same plots from which were taken samples 1000 to 1003. No. 1044 was grown without the use of fertilizers. No. 1045 was from a plot to which were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1046 and 1047 had, in addition to the mixed minerals, sulphate of ammonia at the rate of 120 and 360 pounds per acre respectively.

1060 to 1063, *Timothy* (*Phleum pratense*).—Grown by the Station in 1892, on the same plots from which samples 1004 to 1007 were taken in 1891. No. 1060 was grown without the use of fertilizers. No. 1061 had the same mineral fertilizers as 1045 above, and 1062 and 1063 were from plots which were treated in the same way as 1046 and 1047 above.

969, 973, 974, and 977 *Timothy and Red-top Hay*.—Grown in Connecticut in 1890, and analyzed during the following winter.

1040 and 1041, *Timothy and Red-top Hay*.—Grown in 1891 and analyzed in the following winter. There were small percentages of grasses other than timothy and red-top.

1021 and 1027, *Tall Red-top* (*Agrostis vulgaris major*).—Grown by the Station in 1891. No. 1021 was from a plot which received dissolved bone-black at the rate of 320 pounds per acre, muriate of potash at the rate of 160 pounds, and nitrate of soda at the rate of 160 pounds per acre. No. 1027 received in addition to the mixed minerals of 1021 nitrate of soda at the rate of 480 pounds per acre.

1064 and 1065, *Tall Red-top* (*Agrostis vulgaris major*).—Grown by the Station in 1892, on the same plots from which samples 1021 and 1027 were taken in the preceding year. They were in bloom at time of taking sample. The plots received the same mineral fertilizers as in 1891. The plot from which 1064 was taken received in addition to the mineral fertilizers 120 pounds of sulphate of ammonia per acre, and 1065, 360 pounds of sulphate of ammonia.

1066 and 1067, *Smaller Red-top* (*Agrostis vulgaris minor*).—Grown by the Station in 1892. In bloom at time of taking sample. No. 1066 was from a plot which received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds, and sulphate of ammonia at the rate of 120 pounds per acre. No. 1067, in addition to the same mixed minerals as 1066, received sulphate of ammonia at the rate of 360 pounds per acre.

1012 and 1013, *Foral Meadow Grass* (*Poa serotina*).—Grown by the Station in 1891. In bloom at time of taking sample. They were from plots to which, in addition to dissolved bone-black at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds, nitrate of soda was applied at the rate of 160 and 480 pounds per acre respectively.

1008 and 1009, *Rye Grass (Lolium peren)*.—Grown by the Station in 1891. Just past bloom at time of cutting. The plot from which 1008 was taken received the same treatment as 1012, and 1009 the same as 1013 above.

1010 and 1011, *Meadow Fescue (Festuca elatior)*.—Grown by the Station in 1891. Seed beginning to form at time of taking sample. The plot from which 1010 was taken received in addition to the mixed minerals, nitrate of soda at the rate of 160 pounds per acre, and that from which 1011 was taken, nitrate of soda at the rate of 420 pounds per acre.

1050 and 1051, *Kentucky Blue Grass (Poa pratensis)*.—Grown by the Station in 1892. In milk at time of taking sample. The plots received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160, and in addition, that of 1050 had 120 and 1051 360 pounds of sulphate of ammonia.

1048 and 1049, *Oat Grass (Avena elatior)*.—Grown by the Station in 1892. In milk at time of taking sample. The plots upon which these were grown received mixed minerals as 1050 and 1051, and in addition that of 1048 received sulphate of ammonia at the rate of 120 pounds per acre, and 1049 at the rate of 360 pounds per acre.

1068 and 1069, *Brome Grass (Bromus tectorum)*.—Grown by the Station in 1892. Seed beginning to form at time of taking sample. The plot from which 1068 was taken received in addition to the mixed minerals, 120 pounds of sulphate of ammonia per acre, and that of 1069 received 360 pounds of sulphate of ammonia.

1109 to 1111, *Hungarian (Setaria Italica)*.—These were grown by the Station in 1892, and were in full bloom at time of taking sample. No. 1109 was grown upon a plot which received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. It made small growth, was yellowish in color, and about 6 to 10 inches in height at time of cutting. No. 1110 was grown upon a plot which received, in addition to the same mixed minerals as 1109, sulphate of ammonia at the rate of 120 pounds per acre. There was a medium growth and of fair color. No. 1111 was from a plot which received, in addition to the same mixed minerals as 1109, 360 pounds of sulphate of ammonia per acre. It made good growth and had good color.

971, 972, 975 and 976, *Roxen Hay*.—Grown in 1890 in Connecticut.

1042 and 1043, *Oat and Vetch Hay*.—Grown by the Station in 1892.

FIELD CURED GRAIN.

1030 to 1033, *Corn*.—These samples were from the same plots from which were taken the samples of stover, 1017 to 1020.

1073 to 1084, *Oats*.—Grown in a soil test experiment by the Station in 1892. 1073, 1074, and 1075 were grown without the addition of fertilizers. The plot from which 1076 was taken, received nitrate of soda at the rate of 320 pounds per acre; that of 1077 dissolved bone-black at the rate of 320 pounds per acre; 1078, muriate of potash at the rate of 160 pounds per acre; 1079, 160 pounds of nitrate of soda and 320 pounds of dissolved bone-black per acre; 1080, 160 pounds of nitrate of soda and 160 pounds of muriate of potash; 1081 received 320 pounds of dissolved bone-black and 160 pounds of muriate of potash; 1082 received 160 pounds of nitrate of soda, 320 pounds of dissolved bone-black and

160 pounds of muriate of potash per acre. No. 1083 was from a plot which received 6 tons of stable manure and 160 pounds of dissolved bone-black, and 1084 was from a plot which received 8 tons of stable manure per acre.

1085 to 1096, *Oats*.—This was from a special nitrogen experiment conducted at Wapping in 1892, the same from which the samples of oat straw, 1097 to 1108, were taken. No. 1085 was from the same plot as 1097, 1086 the same as 1098, 1087 the same as 1099, 1088 the same as 1100, 1089 the same as 1101, 1090 the same as 1102, 1091 the same as 1103, 1092 the same as 1104, 1093 the same as 1105, 1094 the same as 1106, 1095 the same as 1107 and 1096 was from the same plot as 1108.

MILLING PRODUCTS.

978, 982 and 983, 1036 and 1037, *Corn Meal*.—Western grown.

987 and 988, *Corn Meal*.—From corn grown by the Station in 1890.

984, 986, 989, 1038 and 1039, *Wheat Bran*.—From the West.

962, 979, 981, *Buckwheat Middlings*.—Purchased in the autumn of 1891 from the Rockdale Mills, Massachusetts.

1016, 1034 and 1035, —*New Process Linseed Meal*.

TABLE 2.

Proximate Composition of Fodders and Feeding Stuff. — Results of Analyses Herewith Reported Calculated to Water Content at Time of Taking Sample.

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit-free Ext.	Fiber.	Ash.	Pot'n'l En'gy.
		%	%	%	%	%	%	Calor's per lb.
<i>Green Fodders.</i>								
1000	Orchard grass, -	68.78	2.98	1.45	14.12	9.65	3.02	560
1001	Orchard grass, -	66.60	2.80	1.81	15.00	10.81	2.98	605
1002	Orchard grass, -	67.02	2.88	1.50	14.61	10.83	3.16	590
1003	Orchard grass, -	71.68	2.72	1.40	12.73	8.73	2.74	510
	Average, -	68.52	2.85	1.54	14.11	10.00	2.98	565
1004	Timothy, -	71.15	2.61	.85	13.98	9.17	2.24	515
1005	Timothy, -	70.66	2.70	.86	14.40	9.19	2.19	525
1006	Timothy, -	70.45	2.69	1.12	13.86	9.74	2.14	535
1007	Timothy, -	71.77	2.95	1.02	13.57	8.78	1.91	515
	Average, -	71.01	2.74	.96	13.95	9.22	2.12	525
1024	Hungarian grass, -	72.74	2.55	.77	14.13	7.74	2.07	450
1025	Hungarian grass, -	72.74	3.30	.78	12.65	7.86	2.67	475
1072	Hungarian grass, -	71.50	3.08	.90	13.26	9.12	2.14	515
	Average, -	72.33	2.98	.81	13.35	8.24	2.29	490
1015	Wheat fodder, -	69.92	3.69	1.03	14.73	9.01	1.62	550
1052	Wheat fodder, -	76.18	2.58	.91	12.50	6.30	1.53	440
1053	Wheat fodder, -	74.25	2.19	.96	12.89	8.13	1.58	475
	Average, -	73.45	2.82	.97	13.37	7.81	1.58	490
1023	Red clover, -	70.19	5.98	1.41	13.60	6.70	2.12	550
1028	Red clover, -	81.33	3.73	.86	8.01	4.33	1.74	335
1112	Red clover, -	75.36	4.74	.76	11.11	6.02	2.01	440
	Average, -	75.63	4.82	1.01	10.90	5.68	1.96	440
1113	Scarlet clover, -	79.55	3.09	.75	8.55	6.27	1.79	365
1022	Cow pea, -	83.59	3.20	.38	7.76	3.28	1.79	280
1114	Cow pea, -	88.28	2.53	.42	4.10	3.23	1.44	200
	Average, -	83.81	2.94	.52	6.80	4.26	1.67	280

* For description of samples, see page 23.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'n'l En'gy.
	<i>Green Fodders.</i>	%	%	%	%	%	%	Calor's per lb.
1014	Oat and pea fodder,	82.95	2.95	.63	7.35	4.73	1.39	305
1070	Oat and pea fodder,	83.77	3.54	.74	6.23	4.26	1.46	300
1071	Oat and pea fodder,	84.64	3.51	.78	5.94	3.70	1.43	285
	Average, - -	83.79	3.33	.72	6.50	4.23	1.43	295
1026	Oat and vetch fodder,	75.42	3.62	.71	11.75	6.47	2.03	435
1029	Barley and pea fodder,	84.12	3.03	.57	6.10	4.28	1.90	355
	<i>Roots and Ensilage.</i>							
963	Mangolds, - -	91.91	.98	.09	5.24	.73	1.05	135
966	Corn ensilage,	80.99	1.70	.59	9.53	5.90	1.29	345
	<i>Field Cured Hay and Fodders.</i>							
1017	Corn stover, - -	32.83	4.70	1.74	34.86	20.76	5.11	1195
1018	Corn stover, - -	28.88	3.95	1.66	36.78	22.50	6.23	1245
1019	Corn stover, - -	40.11	3.93	1.19	29.54	20.32	4.91	1050
1020	Corn stover, - -	42.54	4.63	1.36	28.40	18.20	4.78	1010
	Average, - -	36.09	4.30	1.49	32.42	20.44	5.26	1125
1097	Oat straw, - -	16.63	4.53	2.51	37.51	33.68	5.14	1515
1098	Oat straw, - -	14.40	4.76	2.89	39.51	33.68	4.76	1575
1099	Oat straw, - -	32.43	3.25	2.03	30.07	27.95	4.27	1225
1100	Oat straw, - -	16.97	3.99	2.38	38.21	33.59	4.86	1510
1101	Oat straw, - -	13.80	3.13	2.50	39.37	35.81	5.34	1560
1102	Oat straw, - -	15.28	4.13	2.27	38.04	35.49	4.79	1540
1103	Oat straw, - -	14.17	3.60	2.14	38.68	36.71	4.70	1555
1104	Oat straw, - -	14.33	3.91	2.20	38.26	36.58	4.72	1555
1105	Oat straw, - -	13.22	5.26	2.06	37.79	36.69	4.98	1570
1106	Oat straw, - -	14.80	3.31	2.40	37.93	36.84	4.72	1555
1107	Oat straw, - -	17.28	3.62	2.26	37.49	34.67	4.68	1505
1108	Oat straw, - -	19.26	4.17	2.33	37.30	32.80	4.14	1480
	Average, - -	16.88	3.98	2.33	37.51	34.54	4.76	1515
990	Hay, mixed grasses,	25.23	4.81	2.52	40.81	23.23	3.40	1385
991	Hay, mixed grasses,	22.13	5.69	3.07	40.50	24.70	3.91	1450
992	Hay, mixed grasses,	26.79	4.85	2.53	39.26	22.77	3.80	1350
993	Hay, mixed grasses,	22.56	5.66	3.12	39.60	24.66	4.40	1430
994	Hay, mixed grasses,	32.41	4.69	2.47	35.34	21.64	3.45	1255
995	Hay, mixed grasses,	31.72	5.97	2.79	33.56	22.32	3.64	1270
996	Hay, mixed grasses,	33.08	6.02	2.87	33.45	21.01	3.57	1245
997	Hay, mixed grasses,	32.61	4.97	2.60	34.78	21.48	3.56	1245
998	Hay, mixed grasses,	29.81	6.14	2.86	34.91	22.22	4.06	1300
999	Hay, mixed grasses,	32.70	6.69	2.89	33.35	20.60	3.77	1250
1054	Hay, mixed grasses,	16.15	6.45	2.66	43.12	27.31	4.31	1545
1055	Hay, mixed grasses,	17.53	9.02	2.63	38.97	26.39	5.46	1495
1056	Hay, mixed grasses,	16.80	6.40	2.78	41.01	28.42	4.59	1530
1057	Hay, mixed grasses,	19.71	7.47	2.96	38.18	27.25	4.43	1485
1058	Hay, mixed grasses,	16.92	8.77	2.96	39.05	27.54	4.76	1530
1059	Hay, mixed grasses,	9.39	6.52	2.80	47.15	30.22	3.92	1680
	Average, - -	24.10	6.26	2.78	38.32	24.48	4.06	1400
	<i>Cured Hay & Fodders.</i>							
1044	Orchard grass, -	9.37	7.65	3.77	41.23	29.79	8.19	1625
1045	Orchard grass, -	8.68	7.48	3.69	40.97	30.66	8.52	1630
1046	Orchard grass, -	7.43	10.64	5.06	38.70	29.21	8.96	1675
1047	Orchard grass, -	7.91	14.27	5.02	35.27	29.11	8.42	1675
	Average, - -	8.35	10.00	4.38	39.06	29.69	8.52	1650

* For description of samples, see page 23.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'n'l En'gy.
	<i>Cured Hay & Fodders.</i>	%	%	%	%	%	%	Calor's per lb.
1060	Timothy, - -	10.66	6.03	3.04	44.55	30.23	5.49	1630
1061	Timothy, - -	9.85	5.63	2.68	44.33	31.72	5.79	1635
1062	Timothy, - -	8.56	6.45	2.72	45.20	31.46	5.61	1660
1063	Timothy, - -	12.29	9.38	2.80	41.18	28.80	5.55	1595
	Average, - -	10.34	6.87	2.81	43.82	30.55	5.61	1630
969	Timothy and red-top, - -	9.86	8.62	2.71	42.29	31.07	5.45	1640
973	Timothy and red-top, - -	15.97	7.61	2.52	40.45	28.68	4.77	1530
974	Timothy and red-top, - -	14.31	8.25	2.53	40.65	28.92	5.34	1550
977	Timothy and red-top, - -	18.93	7.05	2.47	40.02	27.14	4.39	1485
1040	Timothy and red-top, - -	10.61	8.15	3.25	44.63	28.17	5.19	1645
1041	Timothy and red-top, - -	8.43	8.06	3.24	44.22	30.78	5.27	1895
	Average, - -	13.02	7.96	2.78	42.04	29.13	5.07	1600
1021	Red-top, tall, - -	8.11	8.09	2.78	47.30	26.43	7.29	1640
1027	Red-top, tall, - -	7.33	12.33	3.12	44.63	24.90	7.69	1655
1064	Red-top, tall, - -	11.11	6.72	2.48	44.20	29.12	6.37	1595
1065	Red-top, tall, - -	10.83	8.30	2.82	43.57	28.43	6.05	1610
	Average, - -	9.35	8.86	2.90	44.92	27.22	6.85	1625
1066	Red-top, smaller, - -	5.62	7.91	3.21	50.05	26.22	6.99	1700
1067	Red-top, smaller, - -	10.48	10.69	3.29	42.26	26.11	7.17	1610
	Average, - -	8.05	9.30	3.25	46.16	26.16	7.08	1655
1012	Fowl meadow grass, - -	10.80	10.76	2.93	37.73	29.29	8.49	1570
1013	Fowl meadow grass, - -	10.44	13.32	2.53	37.84	28.35	7.52	1585
	Average, - -	10.62	12.04	2.73	37.79	28.82	8.00	1580
1008	Rye grass, - -	10.97	11.24	2.60	43.35	24.67	7.17	1585
1009	Rye grass, - -	10.80	9.69	2.42	45.31	24.57	7.21	1580
	Average, - -	10.88	10.47	2.51	44.33	24.62	7.19	1585
1010	Meadow fescue, - -	12.99	9.52	2.51	44.07	24.95	5.96	1565
1011	Meadow fescue, - -	11.16	6.66	2.67	46.06	27.82	5.63	1610
	Average, - -	12.08	8.09	2.59	45.06	26.39	5.79	1580
1050	Blue grass, - -	6.63	12.03	3.77	41.92	29.40	6.25	1710
1051	Blue grass, - -	9.59	13.96	4.08	39.32	26.78	6.27	1665
	Average, - -	8.11	13.00	3.92	40.62	28.09	6.26	1690
1048	Avena elatior, - -	10.75	9.37	2.73	40.06	30.41	6.68	1600
1049	Avena elatior, - -	10.27	10.71	2.97	39.46	29.86	6.73	1615
	Average, - -	10.51	10.04	2.85	39.76	30.13	6.71	1610
1068	Brome grass, - -	9.34	9.64	3.43	44.85	25.59	7.15	1635
1069	Brome grass, - -	8.46	10.07	3.28	44.82	27.17	6.20	1665
	Average, - -	8.90	9.85	3.36	44.84	26.38	6.67	1650
1109	Hungarian, - -	9.49	5.20	2.94	47.95	27.40	7.02	1620
1110	Hungarian, - -	8.30	6.53	2.94	46.60	28.11	7.52	1635
1111	Hungarian, - -	8.27	7.29	2.88	44.37	29.77	7.42	1635
	Average, - -	8.69	6.34	2.92	46.30	28.43	7.32	1630
971	Rowen, - -	15.55	14.62	3.12	37.34	23.92	5.45	1545
972	Rowen, - -	15.12	14.80	3.13	37.07	24.02	5.86	1545
975	Rowen, - -	14.33	14.83	3.34	37.56	23.93	6.01	1560
976	Rowen, - -	13.44	14.50	3.19	38.17	24.51	6.10	1570
	Average, - -	14.61	14.69	3.19	37.53	24.10	5.88	1555
1042	Oat and vetch hay, - -	16.34	10.51	2.34	35.22	28.75	6.84	1110
1043	Oat and vetch hay, - -	11.85	10.40	2.61	37.08	30.36	6.80	1200
	Average, - -	14.09	10.46	2.48	36.60	29.55	6.82	1155
	<i>Field Cured Grain.</i>							
1030	Corn, - - -	10.95	9.79	5.07	71.53	1.17	1.49	1750
1031	Corn, - - -	8.80	9.92	5.34	73.13	1.31	1.50	1795

* For description of samples, see page 23.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Water.	Pro-tein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'n'l En'gy.
1032	Corn, - - -	14.57	9.40	5.06	68.54	1.01	1.42	1680
1033	Corn, - - -	8.56	10.86	5.72	72.03	1.29	1.54	1810
	Average, - -	10.72	9.99	5.29	71.31	1.20	1.49	1760
1073	Oats, - - -	12.64	13.76	5.14	56.27	9.04	3.15	1690
1074	Oats, - - -	12.90	12.89	4.92	58.76	7.31	3.22	1475
1075	Oats, - - -	13.01	11.96	4.73	57.85	9.21	3.24	1670
1076	Oats, - - -	12.38	13.42	4.94	57.61	8.67	2.98	1690
1077	Oats, - - -	11.76	12.52	4.96	58.95	8.63	3.18	1700
1078	Oats, - - -	11.18	13.10	5.12	59.51	8.04	3.05	1715
1079	Oats, - - -	12.04	12.87	5.33	59.04	7.90	2.82	1710
1080	Oats, - - -	12.45	12.97	5.05	58.00	8.59	2.94	1695
1081	Oats, - - -	12.22	12.01	4.73	58.94	8.99	3.11	1685
1082	Oats, - - -	11.91	12.83	5.09	60.20	7.24	2.73	1710
1083	Oats, - - -	12.00	12.87	4.98	59.01	8.25	2.89	1700
1084	Oats, - - -	12.92	13.17	5.19	58.79	7.18	2.75	1690
1085	Oats, - - -	15.57	13.77	5.24	56.00	6.77	2.65	1640
1086	Oats, - - -	13.69	13.53	5.59	57.47	7.04	2.68	1685
1087	Oats, - - -	15.73	13.21	5.13	56.68	6.55	2.70	1635
1088	Oats, - - -	14.99	12.49	5.35	57.20	7.24	2.73	1660
1089	Oats, - - -	14.14	13.90	5.66	58.53	5.26	2.51	1685
1090	Oats, - - -	13.24	14.92	5.57	57.77	5.86	2.64	1695
1091	Oats, - - -	18.47	13.50	4.89	54.49	6.28	2.37	1580
1092	Oats, - - -	13.22	14.21	4.81	56.97	8.20	2.59	1685
1093	Oats, - - -	14.03	14.78	4.49	55.14	8.91	2.65	1655
1094	Oats, - - -	14.31	13.29	4.86	57.18	7.63	2.73	1660
1095	Oats, - - -	13.84	13.68	4.97	57.15	7.73	2.63	1670
1096	Oats, - - -	13.64	14.74	5.11	57.43	6.55	2.53	1680
	Average, - -	13.43	13.35	5.08	57.70	7.63	2.81	1680
	<i>Milling Products.</i>							
978	Corn meal, western,	12.83	9.20	3.86	71.01	1.73	1.37	1690
982	Corn meal, western,	12.96	9.25	3.72	71.20	1.48	1.39	1680
983	Corn meal, western,	13.53	9.13	3.81	70.30	1.85	1.38	1675
1036	Corn meal, western,	16.89	9.14	3.09	67.78	1.77	1.33	1595
1037	Corn meal, western,	16.11	9.49	3.37	68.30	1.39	1.34	1615
	Average, - - -	14.46	9.24	3.57	69.72	1.64	1.37	1651
987	Corn meal, Station,	16.27	9.68	3.73	67.14	1.82	1.36	1620
988	Corn meal, Station,	14.44	9.52	4.28	68.82	1.63	1.31	1670
	Average, - - -	15.35	9.60	4.00	67.98	1.73	1.34	1645
984	Wheat bran, - - -	11.87	15.76	4.74	51.80	10.00	5.83	1640
985	Wheat bran, - - -	10.77	17.18	4.78	50.98	10.24	6.05	1660
986	Wheat bran, - - -	11.93	16.95	4.92	50.63	9.53	6.04	1640
989	Wheat bran, - - -	11.99	16.62	4.81	51.03	10.21	5.34	1650
1038	Wheat bran, - - -	13.05	14.35	4.77	50.22	10.82	6.79	1605
1039	Wheat bran, - - -	12.60	15.24	5.14	49.94	10.67	6.41	1625
	Average, - - -	12.04	16.01	4.86	50.77	10.24	6.08	1635
962	Buckwheat middlings,	12.55	24.65	6.04	49.52	2.89	4.35	1685
979	Buckwheat middlings,	12.62	25.24	6.25	49.57	2.09	4.23	1695
980	Buckwheat middlings,	12.88	23.85	6.08	50.64	2.45	4.10	1690
981	Buckwheat middlings,	13.18	25.07	6.38	48.43	2.60	4.25	1685
	Average, - - -	12.81	24.70	6.19	49.54	2.53	4.23	1690
1016	Linseed meal, - - -	13.36	36.12	2.60	33.82	8.29	5.81	1565
1034	Linseed meal, - - -	12.55	34.11	3.29	35.12	9.27	5.66	1610
1035	Linseed meal, - - -	12.06	34.30	3.18	35.93	8.79	5.74	1605
	Average, - - -	12.66	34.84	3.02	34.96	8.78	5.74	1595

*For description of samples, see page 23.

TABLE 3.

Proximate Composition of Fodders and Feeding Stuffs.—Results of Analyses Herewith Reported, Calculated to Water-Free Substance (Dry Matter).

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	<i>Grasses, Etc.</i>	%	%	%	%	%	Calor's per lb.
1000	Orchard grass, - - -	9.56	4.66	45.20	30.92	9.66	1795
1001	Orchard grass, - - -	8.37	5.42	44.90	32.37	8.94	1820
1002	Orchard grass, - - -	8.75	4.55	44.30	32.83	9.57	1790
1003	Orchard grass, - - -	9.62	4.93	44.96	30.82	9.67	1795
1044	Orchard grass, - - -	8.44	4.16	45.49	32.87	9.04	1790
1045	Orchard grass, - - -	8.19	4.05	44.86	33.57	9.33	1785
1046	Orchard grass, - - -	11.50	5.47	41.80	31.55	9.68	1810
1047	Orchard grass, - - -	15.50	5.45	38.30	31.61	9.14	1820
	Average, - - -	9.99	4.83	43.73	32.07	9.38	1800
1004	Timothy, - - -	9.06	2.94	48.46	31.78	7.76	1785
1005	Timothy, - - -	9.19	2.93	49.09	31.32	7.47	1790
1006	Timothy, - - -	9.12	3.78	46.90	32.96	7.24	1815
1007	Timothy, - - -	10.44	3.62	48.07	31.12	6.75	1820
1060	Timothy, - - -	6.75	3.40	49.87	33.84	6.14	1825
1061	Timothy, - - -	6.25	2.97	49.17	35.18	6.43	1810
1062	Timothy, - - -	7.06	2.98	49.43	34.41	6.12	1820
1063	Timothy, - - -	10.69	3.19	46.95	32.84	6.33	1820
	Average, - - -	8.57	3.23	48.49	32.93	6.78	1810
969	Timothy and red-top, - -	9.56	3.01	46.91	34.47	6.05	1820
973	Timothy and red-top, - -	9.06	2.99	48.15	34.13	5.67	1825
974	Timothy and red-top, - -	9.63	2.95	47.44	33.75	6.23	1810
977	Timothy and red-top, - -	8.69	3.05	49.36	33.48	5.42	1835
1040	Timothy and red-top, - -	9.12	3.64	49.92	31.51	5.81	1835
1041	Timothy and red-top, - -	8.81	3.54	48.28	33.61	5.76	1835
	Average, - - -	9.16	3.19	48.34	33.49	5.82	1825
1021	Red-top, tall, - - -	8.81	3.03	51.47	28.76	7.93	1780
1027	Red-top, tall, - - -	13.31	3.36	48.16	26.87	8.30	1785
1064	Red-top, tall, - - -	7.56	2.79	49.73	32.75	7.17	1790
1065	Red-top, tall, - - -	9.31	3.16	48.87	31.88	6.78	1810
	Average, - - -	9.75	3.08	49.56	30.06	7.55	1790
1066	Red-top, smaller, - -	8.38	3.40	53.03	27.78	7.41	1805
1067	Red-top, smaller, - -	11.94	3.68	47.20	29.17	8.01	1800
	Average, - - -	10.16	3.54	50.11	28.48	7.71	1805
1012	Fowl meadow grass, - -	12.06	3.28	42.30	32.84	9.52	1760
1013	Fowl meadow grass, - -	14.87	2.83	42.25	31.65	8.40	1770
	Average, - - -	13.47	3.05	42.27	32.25	8.96	1765
1008	Rye grass, - - -	12.02	2.92	48.69	27.71	8.06	1775
1009	Rye grass, - - -	10.87	2.71	50.79	27.54	8.09	1775
	Average, - - -	11.75	2.81	49.74	27.62	8.08	1775
1010	Meadow fescue, - - -	10.94	2.89	50.65	28.67	6.85	1800
1011	Meadow fescue, - - -	7.50	3.01	51.84	31.31	6.34	1815
	Average, - - -	9.22	2.95	51.25	29.99	6.59	1810
1050	Blue grass, - - -	12.88	4.04	44.89	31.49	6.70	1830
1051	Blue grass, - - -	15.44	4.51	43.49	29.62	6.94	1835
	Average, - - -	14.16	4.27	44.19	30.56	6.82	1835
1048	Avena elatior, - - -	10.50	3.06	44.88	34.07	7.49	1795

* For description of samples, see page 23.

TABLE 3.—(Continued.)

Lab. No.	KIND.*	Pro-tein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'n'l En'gy.
	<i>Grasses, etc.</i>	%	%	%	%	%	Calor's per lb.
1049	Avena elatior, - - -	11.94	3.31	43.97	33.28	7.50	1800
	Average, - - -	11.22	3.18	44.42	33.68	7.50	1800
1068	Bromus, - - -	10.63	3.78	40.47	28.23	7.89	1805
1069	Bromus, - - -	11.00	3.58	48.96	29.68	6.78	1820
	Average, - - -	10.82	3.68	49.21	28.96	7.33	1815
1024	Hungarian, - - -	9.37	2.81	51.83	28.39	7.60	1785
1025	Hungarian, - - -	12.12	2.86	46.39	28.84	9.79	1750
1072	Hungarian, - - -	10.81	3.16	46.53	31.99	7.51	1795
1109	Hungarian, - - -	5.75	3.24	52.98	30.27	7.76	1790
1110	Hungarian, - - -	7.13	3.21	50.81	30.65	8.20	1785
1111	Hungarian, - - -	7.94	3.14	48.37	32.46	8.09	1784
	Average, - - -	8.85	3.07	49.49	30.43	8.16	1780
990	Mixed grasses, - - -	6.44	3.38	54.58	31.06	4.54	1855
991	Mixed grasses, - - -	7.31	3.94	52.01	31.72	5.02	1860
992	Mixed grasses, - - -	6.63	3.45	53.63	31.10	5.19	1850
993	Mixed grasses, - - -	7.31	4.03	51.13	31.84	5.69	1850
994	Mixed grasses, - - -	6.94	3.66	52.28	32.01	5.11	1855
995	Mixed grasses, - - -	8.75	4.08	49.15	32.69	5.33	1860
996	Mixed grasses, - - -	9.00	4.29	49.98	31.40	5.33	1865
997	Mixed grasses, - - -	7.38	3.86	51.61	31.87	5.28	1855
998	Mixed grasses, - - -	8.75	4.08	49.73	31.66	5.78	1850
999	Mixed grasses, - - -	9.94	4.30	49.55	30.61	5.60	1860
1054	Mixed grasses, - - -	7.69	3.17	51.43	32.57	5.14	1840
1055	Mixed grasses, - - -	10.94	3.19	47.25	32.00	6.62	1815
1056	Mixed grasses, - - -	7.69	3.34	49.29	34.16	5.52	1835
1057	Mixed grasses, - - -	9.31	3.69	47.55	33.93	5.52	1845
1058	Mixed grasses, - - -	10.56	3.57	47.00	33.14	5.73	1840
1059	Mixed grasses, - - -	7.19	3.09	52.04	33.35	4.33	1855
	Average, - - -	8.24	3.70	50.51	32.19	5.36	1850
1015	Wheat fodder, - - -	12.25	3.43	48.97	29.95	5.40	1840
1052	Wheat fodder, - - -	10.81	3.84	52.48	26.44	6.43	1830
1053	Wheat fodder, - - -	8.50	3.71	50.07	31.59	6.13	1835
	Average, - - -	10.52	3.66	50.51	29.32	5.99	1835
1097	Oat straw, - - -	5.44	3.02	44.98	40.39	6.17	1815
1098	Oat straw, - - -	5.56	3.37	46.16	39.35	5.56	1840
1099	Oat straw, - - -	4.81	3.01	44.50	41.36	6.32	1815
1100	Oat straw, - - -	4.81	2.87	46.02	40.45	5.85	1820
1101	Oat straw, - - -	3.69	2.90	45.68	41.54	6.19	1815
1102	Oat straw, - - -	4.88	2.69	44.89	41.88	5.66	1820
1103	Oat straw, - - -	4.19	2.49	45.07	42.78	5.47	1815
1104	Oat straw, - - -	4.56	2.57	44.66	42.70	5.51	1820
1105	Oat straw, - - -	6.06	2.37	43.55	42.28	5.74	1810
1106	Oat straw, - - -	3.88	2.82	44.52	43.24	5.54	1820
1107	Oat straw, - - -	4.38	2.73	45.32	41.91	5.66	1820
1108	Oat straw, - - -	5.17	2.88	46.20	40.62	5.13	1835
	Average, - - -	4.79	2.81	45.13	41.54	5.73	1820
1017	Corn stover, - - -	7.00	2.59	51.90	30.90	7.61	1780
1018	Corn stover, - - -	5.56	2.33	51.71	31.64	8.76	1750
1019	Corn stover, - - -	6.56	1.99	49.32	33.92	8.21	1755
1020	Corn stover, - - -	8.06	2.36	49.59	31.67	8.32	1760
	Average, - - -	6.79	2.32	50.63	32.03	8.23	1760

* For description of samples, see page 23.

TABLE 3.—(Continued.)

Lab. No.	KIND.*	Pro-tein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	<i>Grasses, etc.</i>	%	%	%	%	%	Calor's per lb.
971	Rowen, - - - -	17.31	3.70	44.22	28.32	6.45	1830
972	Rowen, - - - -	17.44	3.69	43.67	28.30	6.90	1820
975	Rowen, - - - -	17.31	3.90	43.84	27.93	7.02	1820
976	Rowen, - - - -	16.75	3.69	44.00	28.32	7.15	1815
	Average, - - - -	17.20	3.75	43.95	28.22	6.88	1825
1023	Red Clover, - - -	20.06	4.72	45.61	22.48	7.13	1840
1028	Red Clover, - - -	20.00	4.62	42.89	23.20	9.29	1795
1112	Red Clover, - - -	19.25	3.08	45.11	24.44	8.12	1780
	Average, - - - -	19.77	4.14	44.54	23.37	8.18	1805
1113	Scarlet clover, - -	15.13	3.66	41.83	30.62	8.76	1785
1022	Cow pea vines, - -	19.50	2.30	47.30	20.01	10.89	1710
1114	Cow pea vines, - -	21.63	3.56	34.95	27.58	12.28	1720
	Average, - - - -	20.57	2.93	41.13	23.79	11.58	1715
1014	Oat and pea fodder, -	17.31	3.68	43.10	27.77	8.14	1800
1070	Oat and pea fodder, -	21.81	4.56	38.38	26.28	8.97	1805
1071	Oat and pea fodder, -	22.88	5.05	38.67	24.06	9.34	1805
	Average, - - - -	20.67	4.43	40.05	26.03	8.82	1805
1026	Oat and vetch fodder, -	14.75	2.88	47.81	26.31	8.25	1775
1042	Oat and vetch fodder, -	12.56	2.80	42.10	34.36	8.18	1775
1043	Oat and vetch fodder, -	11.81	2.96	43.08	34.44	7.71	1790
	Average, - - - -	13.04	2.88	44.33	31.70	8.05	1785
1029	Barley and pea fodder, -	19.06	3.58	38.40	26.98	11.98	1720
	<i>Roots and Ensilage.</i>						
963	Mangolds, - - - -	12.06	1.18	64.79	8.97	13.00	1645
966	Corn ensilage, - - -	8.94	3.12	50.14	31.04	6.76	1805
	<i>Grain.</i>						
1030	Corn, - - - -	11.00	5.69	80.32	1.32	1.67	1965
1031	Corn, - - - -	10.88	5.85	80.19	1.44	1.64	1970
3032	Corn, - - - -	11.00	5.92	80.23	1.19	1.66	1965
1033	Corn, - - - -	11.88	6.25	78.77	1.41	1.60	1980
	Average, - - - -	11.19	5.93	79.88	1.34	1.66	1970
1073	Oats, - - - -	15.75	5.88	64.41	10.35	3.61	1930
1074	Oats, - - - -	14.81	5.65	67.46	8.39	3.69	1930
1075	Oats, - - - -	13.75	5.43	66.50	10.59	3.73	1915
1076	Oats, - - - -	15.31	5.64	65.75	9.90	3.40	1930
1077	Oats, - - - -	14.19	5.62	66.80	9.78	3.61	1925
1078	Oats, - - - -	14.75	5.76	67.01	9.05	3.43	1935
1079	Oats, - - - -	14.63	6.06	67.12	8.98	3.21	1945
1080	Oats, - - - -	14.81	5.77	66.24	9.82	3.36	1935
1081	Oats, - - - -	13.68	5.39	67.14	10.25	3.54	1925
1082	Oats, - - - -	14.56	5.78	68.34	8.22	3.10	1940
1083	Oats, - - - -	14.63	5.66	67.05	9.37	3.29	1935
1084	Oats, - - - -	15.13	5.96	67.51	8.24	3.16	1945
1085	Oats, - - - -	16.31	6.21	66.32	8.02	3.14	1950
1086	Oats, - - - -	15.68	6.43	66.58	8.16	3.10	1955
1087	Oats, - - - -	15.68	6.09	67.26	7.77	3.20	1945
1088	Oats, - - - -	14.69	6.30	67.28	8.52	3.21	1950
1089	Oats, - - - -	16.19	6.59	68.17	6.13	2.92	1960
1090	Oats, - - - -	17.19	6.42	66.59	6.75	3.05	1955
1091	Oats, - - - -	16.56	6.00	66.83	7.70	2.91	1945

*For description of samples, see page 23.

TABLE 3.—(Continued.)

Lab. No.	KIND.*	Pro-tein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Pot'nl En'gy.
	<i>Grain.</i>	%	%	%	%	%	Calor's per lb.
1092	Oats, - - - -	16.38	5.54	65.65	9.45	2.98	1945
1093	Oats, - - - -	17.19	5.22	64.14	10.37	3.08	1925
1094	Oats, - - - -	15.50	5.68	66.73	8.90	3.19	1935
1095	Oats, - - - -	15.88	5.77	66.33	8.97	3.05	1940
1096	Oats, - - - -	17.06	5.91	66.50	7.59	2.94	1945
	Average, - - -	15.43	5.87	66.65	8.80	3.25	1940
	<i>Milling Products.</i>						
978	Corn meal, western, - -	10.56	4.43	81.46	1.98	1.57	1935
982	Corn meal, western, - -	10.63	4.27	81.80	1.70	1.60	1930
983	Corn meal, western, - -	10.56	4.41	81.30	2.14	1.59	1935
1036	Corn meal, western, - -	11.00	3.72	81.54	2.13	1.61	1920
1037	Corn meal, western, - -	11.31	4.02	81.41	1.66	1.60	1925
	Average, - - -	10.81	4.17	81.50	1.92	1.60	1930
987	Corn meal, Station, - -	11.56	4.45	80.19	2.18	1.62	1935
988	Corn meal, Station, - -	11.13	5.00	80.43	1.90	1.54	1950
	Average, - - -	11.35	4.72	80.31	2.04	1.58	1945
984	Wheat bran, - - - -	17.88	5.37	58.76	11.37	6.62	1865
985	Wheat bran, - - - -	19.25	5.36	57.14	11.47	6.78	1865
986	Wheat bran, - - - -	19.25	5.58	57.49	10.82	6.86	1865
989	Wheat bran, - - - -	18.88	5.46	57.99	11.60	6.07	1875
1038	Wheat bran, - - - -	16.50	5.49	57.76	12.44	7.81	1845
1039	Wheat bran, - - - -	17.44	5.88	57.14	12.21	7.33	1865
	Average, - - -	18.20	5.52	57.72	11.65	6.91	1860
962	Buckwheat middlings, -	28.19	6.91	56.62	3.31	4.97	1930
979	Buckwheat middlings, -	28.88	7.15	56.74	2.39	4.84	1940
980	Buckwheat middlings, -	27.38	6.98	58.13	2.81	4.70	1935
981	Buckwheat middlings, -	28.88	7.35	55.78	3.10	4.89	1945
	Average, - - -	28.33	7.10	56.82	2.90	4.85	1940
1016	Linseed meal, new process,	41.69	3.00	39.04	9.57	6.70	1805
1034	Linseed meal, new process,	39.00	3.76	40.15	10.61	6.48	1830
1035	Linseed meal, new process,	39.00	3.61	40.86	10.00	6.53	1825
	Average, - - -	39.90	3.46	40.01	10.06	6.57	1820

* For description of samples, see page 23.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

BY CHAS. D. WOODS AND C. S. PHELPS.

The special nitrogen experiment on grasses reported upon in the Reports of this Station for 1890 and 1891 have been continued during the present year.

PURPOSE OF THE EXPERIMENT.

The experiment was undertaken for the purpose of studying the effect of nitrogenous fertilizers upon grass as shown by:

1. The yield of grass and hay per acre.
2. The financial results.
3. The chemical composition and feeding value of the crop.

DETAILS OF THE EXPERIMENT.

The general plan of the experiment is similar to that of the special nitrogen experiments conducted with corn, and is given at length, together with the plan of the field, in previous Reports of the Station.*

The field has a slope to the south and southwest, but not enough to occasion the washing of fertilizers from one plot to another. The plots contained one-eighth acre each, and were laid out so as to conform to the slope of the field. They are 302.5 feet long by 18 feet wide, with unfertilized strips 3 feet wide between each plot.

The soil is a medium heavy loam, and the sub-soil is slightly clayey and adhesive. The soil was in a comparatively low state of fertility, as is shown by the yield on the unmanured plots. The land is not quickly affected by drought, and appears to retain fertilizers readily. The natural drainage is good.

The field had been in grass for several years, without the application of fertilizers of any kind until 1890. The principal grasses on the field are timothy, red-top, and Kentucky blue grass, with a slight admixture of clover and some weeds. Mineral fertilizers (potash and phosphoric acid) were applied to all the

*Report of this Station, 1890, pp. 45 and 46, and 1891, pp. 30 and 31.

manured plots and in addition nitrogen in the form of nitrate of soda, sulphate of ammonia or dried blood, at the rate of 25, 50 or 75 pounds of nitrogen per acre, was applied to all of the plots except two.

This year reports are made only upon plots o (unmanured), 6a (mixed minerals), and 7, 8 and 9 (nitrate of soda).

NOTES DURING GROWTH.

Season of 1890.—The fertilizers were applied April 29th. On May 1st, there was a rainfall of .15 inches, and from the 4th to the 6th of May, the rainfall amounted to 1.8 inches. This heavy fall of rain did not produce any apparent surface flow on the field.

Notes taken one week from the date of application show that there was considerable response to the fertilizers on all the plots supplied with nitrogen, while the plots having mixed minerals only, showed very little advance over the unmanured plots. In fact, the mineral plots gained but little over the unmanured plots until two or three weeks after the fertilizers were applied.

On June 10th, it was noted that the best growth was upon the plots which had received the most nitrogen. At this date, the blue grass was in full bloom, while the timothy heads were only one-fourth to one-third grown. The crop on the mixed mineral plots appeared to be about one-third heavier than that upon the unmanured plots, and the proportion of clover was much greater than on the plots to which nitrogen had been applied.

At the time of cutting, June 25th, the principal grasses were timothy and red-top. The timothy was beginning to blossom. The heads of the red-top were about three-fourths grown. The blue grass was not as noticeable as it had been earlier, and had pretty generally seeded, and on the unmanured plots was dry and woody. Red and white clover were a little past full bloom. There was a large proportion of clover, especially of white clover, on the mixed mineral plots. The grass on the plots directly entering into the experiment was cut June 25th. A Eureka machine (center cut) was used, and the grass on the unfertilized strips between the plots was left standing until the crop on the plots was harvested. The hay was weighed and put in the barn the afternoon of the 26th.

• *Season of 1891.*—The fertilizer was applied May 1st. On the 3d there was a rainfall of .15 inches.

Notes taken May 8th show there were but little differences between the fertilized plots. The proportion of clover was much less than in 1890.

The first differences in growth on the plots supplied with different fertilizers were noticed May 14th. On May 15th and 16th there was a heavy rain, followed by a rapid growth on all the plots.

June 1st the following notes were taken: The proportion of fine grasses greater than in 1890. The Kentucky blue grass coming into bloom on all the plots.

All the plots made slow growth during the first half of June, and at the middle of the month the Kentucky blue grass was beginning to dry and turn brown.

On June 23d, it was noted that the growth on all the plots was much improved by the heavy rain of the 18th and 19th. A dense bottom growth and an increase in the proportion of timothy were especially noted.

At the time of cutting, June 29th, the principal grasses were timothy, red-top, and blue grass. The blue grass had generally seeded, and had become dry and woody on all the plots. The timothy was coming into bloom. The red-top was nearly full grown, and much of it in bloom. The proportion of fine grasses, and especially blue grass, was greater on all the plots than in 1890. The crop from all the plots was weighed and put into the barn between 2 and 4.30 P. M., June 30th.

The grass on the unmanured strips between the plots was cut and removed several days before the crop on the plots was harvested.

Season of 1892.—This season the fertilizers were applied April 26th, with the exception of one-third of the nitrate of soda for plots 8 and 9, which was applied May 26th.

On May 10th the grasses on the nitrate of soda plots began to show the effects of the fertilizers. The growth on the mixed mineral plot was apparently not yet affected by fertilizers.

On May 19th it was noted that the grasses on nitrate of soda plots were growing rapidly, the growth being heavier and darker colored as the amount of nitrogen used increased. The growth on the mixed mineral plots was slightly better than that on the unmanured.

On June 7th it was noted that the growth on the unmanured plots was thin and spindling, being mostly Kentucky blue grass with a little timothy, 6 to 8 inches high. The grass on the nitrate of soda plots was mostly Kentucky blue grass; the proportion of blue grass being greater than in the past two seasons. The other grasses were timothy and red-top. Proportion of timothy was greatest on plots which received the most nitrogen. The growth on the mixed mineral plot (6a) was mostly Kentucky blue grass and red and white clover, being about half clover. The Kentucky blue grass was coming into bloom on all the plots and was in full bloom by June 10th.

At the time of cutting, June 22d, the grasses on the unmanured and mixed mineral plots were largely Kentucky blue grass, which was dry and woody, and small proportions of timothy and red-top nearly grown. The growth on the nitrate of soda plots was largely Kentucky blue grass, the proportions of the blue grass being greater than in 1890 and 1891. It was seeded, dry and woody. The timothy was coming into bloom and the red-top about three-fourths grown. The proportions of timothy were the greatest on the heavily fertilized plots 8 and 9. There was but little clover on the nitrate of soda plots. The grass on the mixed mineral plot was light and thin, being mostly Kentucky blue grass. The proportions of clover were much larger than on the other plots, being about half of the entire weight.

The grasses were cut the afternoon of June 22d. June 23d was rainy. On the 24th the crop was partially dried and cocked. It was rainy every day until June 29th, on which day the crop was harvested and sampled.

RESULTS OF THE EXPERIMENTS.

In 1891, the proportion of fine grasses, especially Kentucky blue grass, was greater than in 1890, and in 1892 the proportions are still greater. The total yields have also greatly decreased.

This is probably due in part to the increase of fine grasses and in part to the season. The season of 1890 was the most favorable of the three for grass. Table 4, which follows, gives the comparative yield per acre for the three seasons, 1890, 1891, 1892.

TABLE 4.
SPECIAL NITROGEN EXPERIMENT ON GRASS.

Yield of Hay per Acre.

Yield in 1890 indicated by —————, weights in Roman.

Yield in 1891 indicated by ~~~~~, weights in Fullface.

Yield in 1892 indicated by , weights in Italics.

No. of Plot.	FERTILIZERS.		YIELD PER ACRE. (11 % Water.)	
	Kind.	Year.	Comparative Scale.	Lbs.
0	Nothing. - -	1890	—————	1920
		1891	~~~~~	1722
		1892		1274
7	{ Mixed Minerals, - Nitrate of Soda, - (25 lbs. Nitrogen,)	1890	—————	4759
		1891	~~~~~	3394
		1892		3018
8	{ Mixed Minerals, - Nitrate of Soda, - (50 lbs. Nitrogen,)	1890	—————	5874
		1891	~~~~~	4505
		1892		4133
9	{ Mixed Minerals, - Nitrate of Soda, - (75 lbs. Nitrogen,)	1890	—————	6032
		1891	~~~~~	4282
		1892		4696
6a	{ Ds. Bone-bk. { Mx. Mur. Potash. { Min.	1890	—————	3353
		1891	~~~~~	2201
		1892		1980

In the table (4) the weights as given are calculated to a uniform water basis of 11 per cent. (89 per cent. dry matter). The comparative uniformity of the yield in previous years from the unfertilized plots and those to which mixed minerals were applied indicated a fairly uniform soil. The proportions of clover were much the same in 1892 as in 1891, being small on all the plots except the mixed mineral plot. The mineral fertilizers used alone have favored the growth of clover and increased but little the growth of grasses during all three years. The application of

nitrogen has favored the growth of grasses and had but little effect on the growth of clover, though the same amount of mixed minerals has been applied to all fertilized plots. It has become more evident each year that Kentucky blue grass was not a favorable grass to grow with timothy and red-top. The blue grass has been in full bloom when the other grasses were about half grown, and before the timothy and red-top were grown the blue grass had become seeded, dry, and woody.

FINANCIAL RESULTS.

Table 5, which follows, shows the kinds and amounts of fertilizers applied, their cost, the value of the increased yield, and the gain or loss per acre.

TABLE 5.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Weight and Cost of Fertilizers per Acre, Increase of Crop over that of the Nothing Plots, Value of the Increase, and Gain or Loss (-) per Acre.

Results for 1890 in Roman, for 1891 in Fullface, and for 1892 in Italics.

No. of Plot.	FERTILIZERS.	Weight of Fertilizers.	Year.	Cost of Fertilizers.	Total Crop (11 % of Water).		Increase over Nothing Plots.	Value of Increase.	Net Profit or Loss (-).
		Lbs.			Lbs.	Lbs.			
0	Nothing, - - -	—	1890	—	1920	—	—	—	—
			1891	—	1722	—	—	—	—
			1892	—	1274	—	—	—	—
7	{ Mixed Minerals, as 6a, - Nitrate of Soda, - - (25 lbs. Nitrogen,) - -	{ - 480 - 160 - - }	1890	12.00	4750	2389	14.33	2.37	
			1891	12.00	3394	1699	12.74	74	
			1892	12.00	3018	1744	13.08	1.08	
8	{ Mixed Minerals, as 6a, - Nitrate of Soda, - - (50 lbs. Nitrogen,) - -	{ - 480 - 320 - - }	1890	15.96	5874	3504	21.02	5.10	
			1891	15.96	4505	2810	21.08	5.12	
			1892	15.96	4133	2859	21.45	5.49	
9	{ Mixed Minerals, as 6a, - Nitrate of Soda, - - (75 lbs. Nitrogen,) - -	{ - 480 - 480 - - }	1890	19.92	6032	3662	21.97	2.09	
			1891	19.92	4282	2587	19.40	-52	
			1892	19.92	4696	3422	25.68	5.76	
6a	{ Dissolved Bone-black, { Mix'd Muriate of Potash, { Mins.	{ 320 160 - }	1890	8.00	3353	983	5.90	-2.10	
			1891	8.00	2201	506	3.80	-4.20	
			1892	8.00	1980	706	5.31	-2.69	

The cost of the fertilizers is taken at cash rates in ton lots for the ingredients, dissolved bone-black, potash, etc. Two dollars per ton are added to cover the cost of mixing, freight, etc. In the experiment of 1890 the hay was valued at \$12 per ton, and in 1891 and 1892 at \$15 per ton. In 1890 there was a fair return from the application of fertilizers where nitrogen entered into the mixture. In 1891 and 1892 there was a small gain where nitrate of soda was applied at the rate of 25 pounds of nitrogen. In each year there was a gain of about \$5 per acre in the application of nitrate of soda at the rate of 50 pounds of nitrogen. In 1892 there was an equal gain in the application of nitrate of soda at the rate of 75 pounds of nitrogen per acre. In each year the mixed minerals, when used alone, were applied at a loss.

In the experiments of 1890 and 1892 there seems to have been no financial loss in the application of nitrate of soda in large quantities, as the best yield was obtained at the rate of 480 pounds (75 pounds nitrogen), but in 1891 the case seems to have been different. The yield has in general increased as the proportion of nitrogen used was increased. The limit of profit appears to be 250 to 300 pounds of nitrate of soda per acre.

CHEMICAL COMPOSITION OF THE CROP.

Immediately preceding the field weighings of the crop samples, representing as nearly as practicable the hay of each plot, were taken for analysis. Table 6 gives the results of the analysis of the crop for three years, calculated on water-free substance.

In the last column there are given the percentages of water at the time of putting the hay into the barn. It will be noted that there is a wide variation in these percentages, not only in different seasons, but in the hay from different plots of the same season. In the yield per acre, as given in tables 4 and 5, this variation in water content has been overcome by calculating the yield per acre to a uniform water basis of 11 per cent. If this had not been done, the apparent results of the experiment would have been quite different from those given in the tables, since the varying percentages of water make very great differences in the field weights of the crop. For instance, in 1890, plot 9 gave a yield as indicated by the field weight of 7344 pounds, and plot 12 of 6904 pounds, but when calculated to a uniform water content, the results are nearly identical, being 5357 pounds in case of plot 9 and 5383 pounds in case of plot 12.

TABLE 6.

SPECIAL NITROGEN EXPERIMENT ON GRASS.

Proximate Composition of Hay, Calculated on Water-free Substance.

Results for 1890 in Roman, for 1891 in Fullface, and for 1892 in Italics.

No. of Plot.	FERTILIZERS.	Year.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Water at Time of Harvest.
			%	%	%	%	%	%
0	Nothing, - - - -	1890	7.31	3.63	52.86	31.23	4.97	21.9
		1891	6.44	3.38	54.58	31.06	4.54	25.2
		<i>1892</i>	<i>7.69</i>	<i>3.17</i>	<i>51.43</i>	<i>32.57</i>	<i>5.14</i>	<i>16.2</i>
7	{ Mixed Minerals, as 6a, - - -	1890	8.37	3.71	48.83	33.54	5.55	26.9
		1891	6.94	3.66	52.28	32.01	5.11	32.4
		<i>1892</i>	<i>7.69</i>	<i>3.34</i>	<i>49.29</i>	<i>34.16</i>	<i>5.52</i>	<i>16.8</i>
8	{ Mixed Minerals, as 6a, - - -	1890	8.09	3.49	48.69	34.61	5.12	29.1
		1891	8.75	4.08	49.15	32.69	5.33	31.7
		<i>1892</i>	<i>9.31</i>	<i>3.69</i>	<i>47.55</i>	<i>33.93</i>	<i>5.52</i>	<i>19.7</i>
9	{ Mixed Minerals, as 6a, - - -	1890	9.19	3.51	47.59	34.55	5.16	27.0
		1891	9.00	4.29	49.98	31.40	5.33	33.0
		<i>1892</i>	<i>10.56</i>	<i>3.57</i>	<i>47.00</i>	<i>33.14</i>	<i>5.73</i>	<i>16.9</i>
6a	{ Dissolved Bone-black, { Mixed Muriate of Potash, { Min'als.	1890	8.23	3.21	49.96	32.78	5.82	25.7
		1891	6.63	3.45	53.63	31.10	5.19	26.8
		<i>1892</i>	<i>10.94*</i>	<i>3.19</i>	<i>47.25</i>	<i>32.00</i>	<i>6.62</i>	<i>17.5</i>

It will be noted that in each year the application of the large amounts of nitrogen has increased the percentages of protein over that of the crop from the unmanured plots. The percentages of protein were larger in the crops from the mixed mineral plots than in that from the unmanured, and in 1892 the percentage of protein of the crop from the mixed mineral plot is higher than that from any of the plots to which nitrogen was applied. This, as has been pointed out in previous reports, is due to the large amount of clover which the crop from the mixed mineral plots contained. This year samples of the grasses from the mixed mineral plots were analyzed separately. The results of the analysis of the grasses from the mixed mineral plots and that of the total crop are given in the table on the next page.

* This high percentage of protein is due to the large amount of clover in the crop from this plot. See discussion on next page.

	GRASSES FROM PLOT 6a.	TOTAL CROP FROM PLOT 6a.
Protein, - - - - -	7.19	10.94
Fat, - - - - -	3.09	3.19
Nitrogen-free extract, - - - - -	52.04	47.25
Fiber, - - - - -	33.35	32.00
Ash, - - - - -	4.33	6.62

As shown in the table, the protein is nearly four per cent. less in the grasses than in the total yield. The percentage of protein in the grasses alone from the mixed mineral plot is lower than that from any of the other plots.

The variation in percentage of protein from year to year upon the same plots is difficult to account for. In 1890 a relatively larger amount of clover grew than in either of the succeeding years upon the plots to which nitrogen was applied. It was thought last year that the decrease in percentages of protein on the different plots was due to the fact that there was less clover on all the plots in 1891 than in 1890, but in 1892 the proportions of clover are still relatively as small as in 1891 on all of the plots except the mixed mineral plot, and yet the percentages of nitrogen are the highest that they have been found at all. Especially is this true on the plots (8 and 9) which have received the largest amounts of nitrogen.

In each year the effects of nitrogenous fertilizers upon the percentages of protein in the grass are quite strikingly shown. The percentage of nitrogen (protein) has been considerably increased where the larger quantities of nitrogen were used. In this way the feeding value has also been increased. This two-fold use of nitrogen shows the importance of supplying grasses with abundance of this element, either in the form of stable manure, or fertilizers, like nitrate of soda, sulphate of ammonia, Peruvian guano, etc. The use of nitrate of soda in the spring at the rate of 150 to 200 pounds per acre on land which has been previously well fertilized with stable manure may be made to give profitable results.

In table 7 there are given the yield of dry matter and the approximate constituents per acre for all three years. It will be noticed that the pounds of protein removed in the crop increased much faster than the dry matter per acre. This was, of course, to have been expected from the results of the chemical analysis.

TABLE 7.

Special Nitrogen Experiment on Grass. Water-free Substance and Proximate Ingredients per Acre.

Results for 1890 in Roman, for 1891 in Fullface, and for 1892 in Italics.

No. of Plot.	FERTILIZERS.	Year.	Water-free Sub-	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			stance at Harvest.					
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0.	Nothing, - - - - - {	1890	1707	125	62	902	533	85
		1891	1531	99	52	836	475	69
		1892	1147	88	36	590	374	59
7.	Mixed Minerals, as 6a, - - - { Nitrate of Soda, (25 lbs. Nitrogen,) {	1890	4230	354	157	2065	1419	235
		1891	3017	209	110	1578	966	154
		1892	2716	209	91	1338	928	150
8.	Mixed Minerals, as 6a, - - - { Nitrate of Soda, (50 lbs. Nitrogen,) {	1890	5221	423	182	2542	1807	267
		1891	4004	350	163	1969	1309	213
		1892	3720	346	137	1769	1263	205
9.	Mixed Minerals, as 6a, - - - { Nitrate of Soda, (75 lbs. Nitrogen,) {	1890	5357	492	188	2550	1850	277
		1891	3806	342	163	1903	1195	203
		1892	4227	446	151	1987	1401	242
6a.	Dissolved Bone-black, { Mixed Muriate of Potash, { Minerals. {	1890	2989	246	96	1493	980	174
		1891	1956	130	67	1049	608	102
		1892	1782	195	57	842	570	118

It is of interest to note the relations between the nitrogen supplied in the fertilizers and that removed by the crop during the three years in which the experiment has been conducted. It has been seen (page 41) that nitrogen when applied in the form of nitrate of soda at the rate of 50 pounds of nitrogen per acre, was used in every case at a pecuniary profit. It does not, however, necessarily follow from this that it was applied without loss of nitrogen. As shown in the table (8) which follows, about 50 pounds of nitrogen per acre were removed in the crops from the unmanured plots. During the three years on plot 7 there have been applied 75 pounds of nitrogen, and 124 pounds have been removed, or 49 pounds more were removed than were applied in the fertilizer. This is practically the same amount as that removed from the unmanured plot. On plot 9, 225 pounds of nitrogen were supplied in the fertilizer and only 205 removed in the crop.

That is, there were 20 pounds less nitrogen in the crop than were supplied in the fertilizer. If we assume that the soil of all of the plots would have furnished the same amounts of nitrogen in the crop as did the unmanured plot, then it will be seen that from plot 7 all of the nitrogen supplied was gotten back; that there were 21 pounds of nitrogen lost on plot 8, and 70 pounds on plot 9.

Plots 7, 8 and 9 had the same amount of mineral fertilizers applied as the mixed mineral plot, 6a. If we assume that these plots (7, 8 and 9) would have yielded with the minerals alone a crop containing equal amounts of nitrogen with that obtained from 6a, where the mixed minerals were used alone, it will be seen that on plot 7 there was a loss of 42 pounds of nitrogen, on plot 8 of 62, and on plot 9 of 111 pounds of nitrogen.

The above points out that even under favorable circumstances and where the fertilizer is applied at a financial advantage, plants may be able to utilize only a portion of the nitrogen which is furnished them in the fertilizer.

TABLE 8.

Amounts of Nitrogen Removed in Crops and Supplied in Fertilizers During Three Years, 1890, 1891, and 1892.

No. of Plot.	FERTILIZERS.	Total Nitrogen removed in crop.	Nitrogen supplied in fertilizers.	Nitrogen removed in excess of that supplied.	Nitrogen removed in excess of that obtained in crop from Plot 0.	Nitrogen removed in excess of that obtained in crop from Plot 6a.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Nothing, - - - - -	50	—	50	—	—
7	{ Mixed Minerals, as 6a, - - - - - { Nitrate of Soda, 25 lbs. Nitrogen, }	124	75	49	74	33
8	{ Mixed Minerals, as 6a, - - - - - { Nitrate of Soda, 50 lbs. Nitrogen, }	179	150	29	129	88
9	{ Mixed Minerals, as 6a, - - - - - { Nitrate of Soda, 75 lbs. Nitrogen, }	205	225	-20	155	114
6a	{ Dissolved Bone-black, { Mixed { Muriate of Potash, { Minerals. }	91	—	91	41	—

SUMMARY.

The object of this experiment is to study the effect of nitrogenous fertilizers upon grass, as shown by the yield per acre, the financial results, and the chemical composition of the hay. The plots contained one-eighth acre each, and were separated from each other by unfertilized strips. The field had been in grass for several years, and the soil was considerably reduced in fertility. Mineral fertilizers were applied to all the plots except one, which was left unmanured, and, with one exception, nitrogen was applied to the manured plots at the rate of 25, 50, and 75 pounds per acre.

THE RESULTS.

The addition of mineral fertilizers increased the yield of clover, but did not seem to increase very materially the yield of grasses.

In general the yield of hay increased with the quantity of nitrogen supplied.

The mineral fertilizers, when used alone, were applied at a financial loss.

The application of 160 pounds of nitrate of soda per acre (25 lbs. of nitrogen), in addition to the mixed minerals, gave an average profit during the three years of \$1.40 per acre; 320 pounds of nitrate of soda (50 lbs. of nitrogen) gave an average profit of \$5.24 per acre, and 480 pounds of nitrate of soda (75 lbs. of nitrogen) an average profit of \$2.45 per acre. The returns from 320 pounds were very uniform, the profit being \$5.10, \$5.12 and \$5.49 respectively for the three years.

The application of nitrogenous fertilizers increased the percentages of protein in the crop and somewhat in proportion to the amount of nitrogen supplied.

The increase in the amount of nitrogen in the crop did not equal the increased amount of nitrogen supplied in the fertilizers, implying that the plants were not able to utilize all the nitrogen supplied.

EFFECTS OF DIFFERENT FERTILIZERS UPON THE
COMPOSITION OF OATS AND STRAW.

BY CHAS. D. WOODS.



In the Annual Report of this Station for 1890* there were given the results of the analysis of the crop of oats grown in a "special nitrogen" experiment. It was there stated that the investigation was undertaken with the hope of adding to the knowledge of the effects of different fertilizers upon the percentage composition, and upon the total yield of nutritive ingredients of grain and straw of the oat plant, with special reference to the effect of nitrogenous fertilizers upon the amounts of protein. In continuance of this work, the analyses of the oats and straw from a "special nitrogen" experiment and the grain from a "soil test" experiment with oats were undertaken the present year.

Quite large samples, representing the yield as fairly as practicable, were taken by the Station Agriculturist at the time of harvest. The oats had been cut for some time before harvesting, and were quite dry when the field weighings were made and samples taken. The crop from each plot was threshed separately at harvest, and samples were selected and weighed immediately after threshing. The methods of analyses recommended by the Association of Official Agricultural Chemists were followed.

The results of the analyses are given in the tables. A brief discussion of these results and of those of 1890 follows the tables.

SPECIAL NITROGEN EXPERIMENT.

This experiment was conducted on the farm of Mr. W. W. Green of Wapping, and is described in the article on field experiments in this Report. The field is located in the red sand-stone region of the Connecticut Valley, and has been in grass for several years without manure, and yielded less than one ton of hay per acre. The soil is a light loam with a subsoil of nearly the same character to the depth of 2 to 2 ½ feet.

* Pages 93-106.

TABLE 9.
SPECIAL NITROGEN EXPERIMENT WITH OATS IN 1892.
*Proximate Composition of Water-free Substance of Oats and Oat Straw.**

Plot No.	FERTILIZERS.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
	OATS.		%	%	%	%	%	%
o	Unmanured, - - -	1085	16.31	6.21	66.32	8.02	3.14	2.61
oo	Unmanured, - - -	1086	15.68	6.48	66.58	8.16	3.10	2.51
	Average of Unmanured, -		16.00	6.34	66.45	8.09	3.12	2.56
6	{ Dis. Bone-black, { Mixed } { Muriate of Potash, { Minr'ls. }	1087	15.68	6.09	67.26	7.77	3.20	2.51
6a	Mixed Minerals, as No. 6, -	1088	14.69	6.30	67.28	8.52	3.21	2.35
6b	Mixed Minerals, as No. 6, -	1089	16.19	6.59	68.17	6.13	2.92	2.59
6c	Mixed Minerals, as No. 6, -	1090	17.19	6.42	66.59	6.75	3.05	2.75
	Average of Mixed Minerals, <i>Nitrate of Soda Group.</i>		15.94	6.35	67.32	7.29	3.10	2.55
7	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (25 lbs. N.), }	1091	16.56	6.00	66.83	7.70	2.91	2.65
8	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (50 lbs. N.), }	1092	16.38	5.54	65.65	9.45	2.98	2.62
9	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (75 lbs. N.), }	1093	17.19	5.22	64.14	10.37	3.08	2.75
	<i>Dried Blood Group.</i>							
13	{ Mixed Minerals, as No. 6, - } { Dried Blood (25 lbs. N.), }	1094	15.50	5.68	66.73	8.90	3.19	2.48
14	{ Mixed Minerals, as No. 6, - } { Dried Blood (50 lbs. N.), }	1095	15.88	5.77	66.33	8.97	3.05	2.54
15	{ Mixed Minerals, as No. 6, - } { Dried Blood (75 lbs. N.), }	1096	17.06	5.91	66.50	7.59	2.94	2.73
	OAT STRAW.							
o	Unmanured, - - -	1097	5.44	3.02	44.98	40.39	6.17	.87
oo	Unmanured, - - -	1098	5.56	3.37	46.16	39.35	5.56	.89
	Average of Unmanured, -		5.50	3.19	45.58	39.87	5.86	.88
6	{ Dis. Bone-black, { Mixed } { Muriate of Potash, { Minr'ls. }	1099	4.81	3.01	44.50	41.36	6.32	.77
6a	Mixed Minerals, as No. 6, -	1100	4.81	2.87	46.02	40.45	5.85	.77
6b	Mixed Minerals, as No. 6, -	1101	3.69	2.90	45.68	41.54	6.19	.59
6c	Mixed Minerals, as No. 6, -	1102	4.88	2.69	44.89	41.88	5.66	.78
	Average of Mixed Minerals, <i>Nitrate of Soda Group.</i>		4.55	2.87	45.27	41.31	6.00	.73
7	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (25 lbs. N.), }	1103	4.19	2.49	45.07	42.78	5.47	.67
8	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (50 lbs. N.), }	1104	4.56	2.57	44.66	42.70	5.51	.73
9	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (75 lbs. N.), }	1105	6.06	2.37	43.55	42.28	5.74	.97
	<i>Dried Blood Group.</i>							
13	{ Mixed Minerals, as No. 6, - } { Dried Blood (25 lbs. N.), }	1106	3.88	2.82	44.52	43.24	5.54	.62
14	{ Mixed Minerals, as No. 6, - } { Dried Blood (50 lbs. N.), }	1107	4.38	2.73	45.32	41.91	5.66	.70
15	{ Mixed Minerals, as No. 6, - } { Dried Blood (75 lbs. N.), }	1108	5.17	2.88	46.20	40.62	5.13	.83

* For proximate composition calculated to water content at time of harvest, see table 2, pages 28-31, of this Report.

TABLE 10.

SPECIAL NITROGEN EXPERIMENT WITH OATS IN 1892.

Proximate Ingredients Per Acre in Oats and Straw.

Plot No.	FERTILIZERS.	Laboratory No.	Water-free Oats.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
	OATS.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	Unmanured, - - - -	1085	600	97	37	399	48	19
00	Unmanured, - - - -	1086	449	70	29	299	37	14
	Average of Unmanured, -		525	83	33	349	43	17
6	{ Dis. Bone-black, { Mixed } { Muriate of Potash, { Minerals. }	1087	523	82	32	351	41	17
6a	Mixed Minerals, as No. 6, -	1088	417	61	26	281	36	13
6b	Mixed Minerals, as No. 6, -	1089	515	83	34	351	32	15
6c	Mixed Minerals, as No. 6, -	1090	547	94	35	364	37	17
	Average of Mixed Minerals, -		501	80	32	337	37	15
	<i>Nitrate of Soda Group.</i>							
7	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (25 lbs. N.), - }	1091	726	120	44	485	56	21
8	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (50 lbs. N.), - }	1092	738	121	41	484	70	22
9	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (75 lbs. N.), - }	1093	774	133	40	497	80	24
	<i>Dried Blood Group.</i>							
13	{ Mixed Minerals, as No. 6, - } { Dried Blood (25 lbs. N.), - }	1094	626	97	35	418	56	20
14	{ Mixed Minerals, as No. 6, - } { Dried Blood (50 lbs. N.), - }	1095	655	104	38	434	59	20
15	{ Mixed Minerals, as No. 6, - } { Dried Blood (75 lbs. N.), - }	1096	674	115	40	448	51	20
	OAT STRAW.							
0	Unmanured, - - - -	1097	1292	70	39	581	522	80
00	Unmanured, - - - -	1098	933	52	32	430	367	52
	Average of Unmanured, -		1113	61	35	506	445	66
6	{ Dis. Bone-black, { Mixed } { Muriate of Potash, { Minerals. }	1099	987	47	30	440	408	62
6a	Mixed Minerals, as No. 6, -	1100	1312	63	38	603	531	77
6b	Mixed Minerals, as No. 6, -	1101	1241	46	36	566	516	77
6c	Mixed Minerals, as No. 6, -	1102	1034	50	28	463	433	58
	Average of Mixed Minerals, -		1144	51	33	520	472	68
	<i>Nitrate of Soda Group.</i>							
7	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (25 lbs. N.), - }	1103	1802	76	45	811	771	99
8	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (50 lbs. N.), - }	1104	1885	86	48	842	805	104
9	{ Mixed Minerals, as No. 6, - } { Nitrate of Soda (75 lbs. N.), - }	1105	2994	181	71	1304	1266	172
	<i>Dried Blood Group.</i>							
13	{ Mixed Minerals, as No. 6, - } { Dried Blood (25 lbs. N.), - }	1106	1712	67	48	762	740	95
14	{ Mixed Minerals, as No. 6, - } { Dried Blood (50 lbs. N.), - }	1107	2134	93	58	967	895	121
15	{ Mixed Minerals, as No. 6, - } { Dried Blood (75 lbs. N.), - }	1108	2140	110	62	989	869	110

TABLE II.
SPECIAL NITROGEN EXPERIMENT WITH OATS IN 1892.
Yield Per Acre in Pounds.

Plot No.	FERTILIZERS.	Weight of One Bushel of Oats.	HARVEST WEIGHTS.		WEIGHTS FROM ANALY- SES, OATS AND STRAW.			
			Oats.	Straw.	Water-free Substance.	Protein.	Fat.	Nitrogen- free Extract.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
o	Unmanured, - - -	27.7	710	1550	1892	167	76	979
oo	Unmanured, - - -	28.7	520	1090	1382	122	61	730
	Average of Unmanured, -	28.2	615	1320	1637	145	68	855
6	{ Dis. Bone-black, { Mixed }	26.1	620	1460	1510	129	62	790
	{ Muriate of Potash, { Min'ls }							
6a	Mixed Minerals, as 6, -	27.5	490	1580	1729	124	64	884
6b	Mixed Minerals, as 6, -	27.8	600	1440	1756	129	70	918
6c	Mixed Minerals, as 6, -	28.8	630	1220	1581	144	63	828
	Average of Mixed Minerals, <i>Nitrate of Soda Group.</i>	27.6	585	1425	1644	131	65	855
7	{ Mixed Minerals, as 6, - }	29.1	890	2100	2328	196	89	1297
	{ Nitrate of Soda (25 lbs. N.), - }							
8	{ Mixed Minerals, as 6, - }	28.3	850	2200	2623	207	89	1326
	{ Nitrate of Soda (50 lbs. N.), - }							
9	{ Mixed Minerals, as 6, - }	25.7	900	3450	3768	314	111	1800
	{ Nitrate of Soda (75 lbs. N.), - }							
	<i>Dried Blood Group.</i>							
13	{ Mixed Minerals, as 6, - }	29.2	730	2010	2338	164	83	1179
	{ Dried Blood (25 lbs. N.), - }							
14	{ Mixed Minerals, as 6, - }	29.7	760	2580	2789	197	96	1401
	{ Dried Blood (50 lbs. N.), - }							
15	{ Mixed Minerals, as 6, - }	29.0	780	2650	2814	225	102	1436
	{ Dried Blood (75 lbs. N.), - }							

From the figures in table 10 it will be noticed that the average yield of water-free oats was 24 pounds greater on the unmanured than on the plots to which mixed minerals (phosphoric acid and potash) were applied, and that the yield of water-free straw was 31 pounds less on the unmanured. This means that the total yield (see table 10) of water-free substance (dry matter) averaged nearly the same on the unmanured plots as on those supplied with minerals. From this it might seem that the soil was not in special need of mineral fertilizers and that the increased yield on the plots supplied with mixed minerals and different quantities of nitrogen was due to the action of the nitrogen. The "soil test" portion of the experiment was omitted, and hence it is not

possible from the data to say that the above conclusion may not be correct, but since the yield of oats in plot 7 was increased 225 pounds over that of the mixed mineral plots, and the yield of oats in plots 8 and 9 were only 12 and 44 pounds respectively greater than the yield on plot 7, it seems hardly probable that all of this great increase of 225 pounds could have been due to the nitrogen alone. It is more probable that the soil was deficient in all three of the chief constituents of plant food, and that the application of any one or two would not have produced any very marked difference in yield. The more readily available nitrogen of the nitrate seems to have given better returns than did the same quantities of organic nitrogen applied in the form of dried blood. The relation between the amounts of nitrogen applied in the fertilizers and that found in the crop is discussed on page 54 beyond.

SOIL TEST EXPERIMENT.

This experiment was carried out on the Station land, and was the third crop in a rotation soil test experiment.* The field was planted to corn in 1890, potatoes in 1891, and to oats this year (1892), the order of the plots and the fertilizers used being the same each season.

The plots were seeded with common Western oats at the rate of two and one-half bushels per acre. The seeds germinated well and there was a fairly uniform stand. The crop throughout the season on the plots to which nitrogen had been applied in the fertilizer was in advance of that upon the plots upon which no nitrogen was used. The application of phosphoric acid in the fertilizer appeared to hasten the maturity of the crop. The oats grown on the plots to which phosphoric acid was applied were also heavier, *i. e.*, weighed more per bushel.

Table 12, on the following page, gives the results of the analyses of the grain from each plot entering into the experiment, and the total yield per acre of the nutritive ingredients of the crop.

* Report of this Station, 1890, pp. 69-71; 1891, pp. 81-183, and this Report in article on Field Experiments beyond.

TABLE 12.

SOIL TEST EXPERIMENT WITH OATS IN 1892.

*Proximate Composition of Water-free Substance of Oats and Proximate Ingredients per Acre in Oats.**

Plot No.	FERTILIZERS.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
	<i>Composition.</i>		%	%	%	%	%	%
o	Unmanured, - - -	1073	15.75	5.88	64.41	10.35	3.61	2.52
oo	Unmanured, - - -	1074	14.81	5.65	67.46	8.39	3.69	2.37
ooo	Unmanured, - - -	1075	13.75	5.43	66.50	10.50	3.73	2.20
	Average of Unmanured,		14.77	5.65	66.12	9.78	3.68	2.36
A.	Nitrate of Soda, - -	1076	15.31	5.64	65.75	9.90	3.40	2.45
B.	Dissolved Bone-black, -	1077	14.19	5.62	66.80	9.78	3.61	2.27
C.	Muriate of Potash, - -	1078	14.75	5.76	67.01	9.05	3.43	2.36
D.	{ Nitrate of Soda, - - }	1079	14.63	6.06	67.12	8.98	3.21	2.34
	{ Dissolved Bone-black, - }							
E.	{ Nitrate of Soda, - - }	1080	14.81	5.77	66.24	9.82	3.36	2.37
	{ Muriate of Potash, - - }							
F.	{ Dissolved Bone-black, - }	1081	13.68	5.39	67.14	10.25	3.54	2.19
	{ Muriate of Potash, - - }							
G.	{ Dissolved Bone-black, - }	1082	14.56	5.78	68.34	8.22	3.10	2.33
	{ Muriate of Potash, - - }							
X.	{ Nitrate of Soda, - - }	1083	14.63	5.66	67.05	9.37	3.29	2.34
	{ Stable Manure, - - - }							
Y.	{ Dissolved Bone-black, - }	1084	15.13	5.96	67.51	8.24	3.16	2.42
	{ Stable Manure, - - - }							
	<i>Yield.</i>		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
o	Unmanured, - - -	1073	124	46	506	81	28	—
oo	Unmanured, - - -	1074	98	37	444	55	24	—
ooo	Unmanured, - - -	1075	88	35	424	67	24	—
	Average of Unmanured,		103	39	458	68	25	—
A.	Nitrate of Soda, - -	1076	145	53	622	93	32	—
B.	Dissolved Bone-black, -	1077	108	43	509	75	27	—
C.	Muriate of Potash, - -	1078	104	41	471	64	24	—
D.	{ Nitrate of Soda, - - }	1079	157	65	719	96	34	—
	{ Dissolved Bone-black, - }							
E.	{ Nitrate of Soda, - - }	1080	125	49	557	83	28	—
	{ Muriate of Potash, - - }							
F.	{ Dissolved Bone-black, - }	1081	109	43	534	81	28	—
	{ Muriate of Potash, - - }							
G.	{ Dissolved Bone-black, - }	1082	162	64	759	91	34	—
	{ Muriate of Potash, - - }							
X.	{ Nitrate of Soda, - - }	1083	164	63	751	105	37	—
	{ Stable Manure, - - - }							
Y.	{ Dissolved Bone-black, - }	1084	180	71	804	98	38	—
	{ Stable Manure, - - - }							

* For proximate composition calculated to water content at harvest, see table 2, pp. 29 and 31, of this Report.

COMPOSITION OF THE OATS.

In the table which follows there is given the average composition of the oats, calculated to water-free substance, as found by analysis in the special nitrogen experiments of 1890 and 1892 and in the soil test experiment of 1892. There are also given the minimum and maximum percentages of each of the constituents. There are also appended the results of the analyses of other New England grown oats and the composition of American oats as shown by the average of all the analyses that have been made.

TABLE 13.

Percentage Composition of Water-free Substance of Oats.

	Protein.	Fat.	Nit.-free Extract.	Fiber.	Ash.
	%	%	%	%	%
<i>Special Nitrogen Experiment, 1890.</i>					
Minimum, - - - - -	13.1	5.5	62.4	10.1	2.7
Maximum, - - - - -	16.3	6.2	65.2	16.0	3.4
Average of all, - - - - -	14.7	5.9	64.0	12.5	2.9
Average grown with nitrogenous fertilizers, -	15.1	6.0	64.5	11.6	2.8
<i>Special Nitrogen Experiment, 1892.</i>					
Minimum, - - - - -	14.7	5.2	66.3	6.1	2.9
Maximum, - - - - -	17.2	6.6	68.2	10.4	3.2
Average of all, - - - - -	16.2	6.0	66.5	8.2	3.1
Average grown with nitrogenous fertilizers, -	16.4	5.7	66.1	8.8	3.0
<i>Soil Test Experiment, 1892.</i>					
Minimum, - - - - -	13.7	5.4	64.4	8.2	3.1
Maximum, - - - - -	15.8	6.0	68.3	10.6	3.7
Average of all, - - - - -	14.7	5.7	66.8	9.4	3.4
Average grown with nitrogenous fertilizers, -	14.8	5.8	67.0	9.1	3.3
<i>All other (9) Analyses of New England Grown Oats.</i>					
Minimum, - - - - -	9.1	4.9	67.3	9.9	2.9
Maximum, - - - - -	13.4	6.1	70.8	14.7	4.0
Average, - - - - -	11.1	5.7	68.8	11.0	3.4
<i>All other (30) Analyses of American Oats.*</i>					
Average, - - - - -	13.2	5.6	67.0	10.8	3.4

* Compilation of American Feeding Stuffs.—Jenkins and Winton.

The high percentages of protein in the oats from these experiments, even in those from the unfertilized plots, are very noticeable. In the special nitrogen experiment of 1890, the grain in most cases was not very well developed, and for the most part the

oats were very light, the heaviest weighing 31.7 pounds per bushel. The crop from this year's experiments was considerably heavier.

It will be observed that the percentages of the fiber were greater in the oats of the 1890 experiment than in this year's. This would seem to confirm the suggestion made in the Report of 1890 that a high percentage of fiber, together with a low weight of oats per bushel, indicates an inferior quality of oats. In the experiment of 1890 there was a definite relation between the weight of oats and the percentages of fiber. Light weight oats in that experiment uniformly gave high percentages of fiber. This definite relation does not hold in the experiments of 1892, and is probably not true for heavy, well developed oats. In some cases in this year's experiments the oats which contained the largest percentages of fiber were the heaviest per bushel.

TABLE 14.

RELATION BETWEEN NITROGEN APPLIED IN FERTILIZERS AND PROTEIN (NITROGEN $\times$ 6.25) FOUND IN CROP.

Percentages of Protein in Water-free Substance of Oats and of Straw.

FERTILIZERS.	OATS.			STRAW.		
	Nitrate of Soda Group.	Sulp. of Ammonia Group.	Dried Blood Group.	Nitrate of Soda Group.	Sulp. of Ammonia Group.	Dried Blood Group.
Mixed Minerals and—	%	%	%	%	%	%
25 lbs. Nitrogen, 1890, -	15.7	13.9	14.5	5.1	5.7	5.6
25 lbs. Nitrogen, 1892, -	16.6	—	15.5	4.2	—	3.9
Average, - - -	16.2	—	15.0	4.7	—	4.8
50 lbs. Nitrogen, 1890, -	16.3	15.1	14.1	5.3	6.8	5.3
50 lbs. Nitrogen, 1892, -	16.4	—	15.0	4.6	—	4.4
Average, - - -	16.4	—	15.0	5.0	—	4.9
75 lbs. Nitrogen, 1890, -	16.8	15.0	14.7	6.0	7.5	5.4
75 lbs. Nitrogen, 1892, -	17.2	—	17.1	6.1	—	5.2
Average, - - -	17.0	—	15.9	6.1	—	5.3

The above table shows that the percentages of protein in both the oats and the straw in each experiment increased, as a rule, with the increased application of nitrogen in the fertilizer. It will also be observed that, as a rule, the most marked advance in the percentages of protein was found where the largest applications of nitrogen were made. That is, the percentages of protein

increased in a greater ratio than the increase in amount of nitrogen in the fertilizer. The third 25 pounds of nitrogen seemed to affect the percentage of protein more than the second 25 pounds did.

TABLE 15.
Pounds of Protein per Acre in Crop.

FERTILIZERS.	OATS.			STRAW.			OATS & STRAW		
	Nit. of Soda Group.	Sulp. of Am. Group.	Dried Blood Group.	Nit. of Soda Group.	Sulp. of Am. Group.	Dried Blood Group.	Nit. of Soda Group.	Sulp. of Am. Group.	Dried Blood Group.
Mixed Minerals and—	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
25 lbs. Nitrogen, 1890, -	68	43	53	43	41	40	111	84	93
25 lbs. Nitrogen, 1892, -	120	—	97	76	—	67	196	—	164
50 lbs. Nitrogen, 1890, -	82	58	57	58	53	44	140	111	101
50 lbs. Nitrogen, 1892, -	121	—	104	86	—	93	207	—	197
75 lbs. Nitrogen, 1890, -	100	68	79	78	87	67	178	153	146
75 lbs. Nitrogen, 1892, -	133	—	115	181	—	110	314	—	225

The preceding table gives the pounds of protein in the crop from one acre. This table takes into account the increased percentages of protein resulting from the addition of nitrogen in the fertilizer, and also the increased yield. In the protein from the total crop (both oats and straw) it will be noted that there is in each year, with each kind of nitrogenous fertilizer, an increase in the pounds of protein. It will also be noted here that in general the greatest difference in increase is between the addition of 50 pounds and the addition of 75 pounds of nitrogen per acre.

One hundred and sixty-two pounds of protein contain about 25 pounds of nitrogen. In other words, if a plant could assimilate and change 25 pounds of nitrogen into protein, 162 pounds would be formed. From this it follows that the application of 25 pounds of nitrogen in a fertilizer would, if all taken up and transformed by the growing plant, give 162 pounds of protein in the resulting crop. If we assume that the crop itself furnished no more nitrogen to the plants than was left behind in roots and stubble, and that no nitrogen was taken from the air, it will be seen that the application of more than 25 pounds of nitrogen per acre was, in each instance, made at a loss. That is, there was from 100 to 300 pounds less of protein found in the crop than might have been there if all of

the nitrogen had been taken up and utilized. The protein of the crop was increased more by the application of nitrate of soda than by that of sulphate of ammonia or dried blood, and hence it follows that there was the greatest loss of nitrogen in the use of these fertilizers. This coincides with the results found in the special nitrogen experiment on grass.* In the case of the experiment with oats as in that with grasses, while the nitrogen was applied with pecuniary advantage, both as shown by the increased yield and the increased feeding value of the crop, the increase was obtained with a loss of nitrogen. The experiments were pecuniarily profitable, but viewed from the standpoint of the gain or loss of nitrogen, it is noticeable that there was a loss of a very considerable amount of the nitrogen supplied in the fertilizers.

SUMMARY.

The crops from two special nitrogen experiments with oats and one soil test experiment with oats have been analyzed.

The percentage of protein (nitrogen multiplied by 6.25) increased in both oats and straw with the application of nitrogen in the form of nitrate of soda or sulphate of ammonia, and this increase was somewhat in proportion to the amounts applied.

In the experiment of 1890 the use of different amounts of dried blood in the fertilizer did not materially affect the percentages of protein in either the oats or the straw. In 1892 there was an increase in the protein from the use of the largest amount (75 pounds nitrogen) of dried blood.

There was an increase in pounds of protein per acre in the plots supplied with nitrogenous fertilizers somewhat in proportion to the amounts applied. This increase was greatest in the plots to which nitrate of soda was applied. These results are in accord with observations made by the Station upon the relation of the protein in corn, and in grass, to the nitrogen applied in the fertilizers.

The increase in the amount of nitrogen in the crop did not equal the increase in the amount of nitrogen applied in the fertilizers, implying that the plants were not able to avail themselves of all the nitrogen supplied.

*See this report, p. 44.

METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.



The meteorological records made at the Station during the past year have been similar to those of previous years. A list of the observations taken and the instruments in use will be found in the Report for 1890. In addition to the records made at the Station, the rainfall during the growing season has been recorded by those conducting field experiments in different parts of the State under the supervision of the Station.

The rainfall for the year (36.3 inches) as measured at the Station is much below the average. Six stations of the New England Meteorological Society having records covering a period of ten or more years previous to 1890, give an average annual precipitation of 49.1 inches. The records of this Station for the three years prior to 1892 give an average of 50.3 inches.

The precipitation was smallest during the months of February, April, September, and October. The rainfall for April (.70 inches) was the smallest for any month in the year. This prevented an early start in the grass crop and no doubt lessened the yield considerably. During the portion of the year when most crops were developing (May-August) the rainfall was about the average, so that farm crops as a rule were not greatly injured. Springs and wells, however, have rarely been known as low as in October.

The temperature for the first three months of the year was a little below the average, while the snowfall was light. April gave about the average temperature and the spring opened quite early. The last damaging frost occurred April 30. The weather during the months of May and June was favorable for nearly all farm crops. The summer was unusually warm and conditions were favorable for harvesting the hay crop.

The first killing frost occurred September 21. This gave a growing period of 144 days, since the last damaging frost in the spring. The average growing season for the past five years at Storrs is 142 days. The shortest period, 114 days in 1888, and the longest, 164 days in 1891.

September and October were characterized by unusually dry weather. Pastures were injured and all fall maturing crops suffered. The rainfall for November, however, was above the average, and wells and springs were generally replenished.

Through the kindness of the New England Meteorological Society we are able to publish rainfall records from their stations.

Table 16 gives the rainfall as recorded during the growing season in twenty-six localities in the State, and table 17 gives the summary of observations made at the Station at Storrs.

TABLE 16.
Rainfall during Six Months ending Oct. 31, 1892.

LOCALITY.	OBSERVER.	INCHES PER MONTH.					
		May.	June.	July.	August.	September.	October.
Falls Village, -	M. H. Dean, -	6.43	5.74	6.09	6.13	3.45	1.22
Oxford, -	H. R. Stevens, -	4.58	2.04	4.21	2.43	2.84	1.14
Norwalk, -	G. C. Comstock,* -	5.13	1.48	4.75	5.50	2.30	0.68
Waterbury, -	N. J. Welton,* -	5.55	2.27	4.37	5.30	2.62	0.92
New Hartford, -	R. R. Smith,* -	5.96	4.50	3.86	5.50	2.56	1.28
Canton, -	G. J. Case,* -	6.80	3.48	4.97	8.13	2.53	1.10
W. Simsbury, -	S. T. Stockwell,* -	6.17	3.17	4.47	5.38	2.01	0.90
Hartford, -	Prof. S. Hart,* -	5.65	1.78	3.29	5.51	1.90	1.28
Wallingford, -	Mrs. B. F. Harrison,* -	4.57	1.99	3.47	3.74	2.16	0.92
New Haven, -	Weather Bureau,* -	5.11	2.36	4.33	4.99	1.54	0.94
Middletown, -	C. W. Hubbard,* -	—	1.61	2.63	3.90	2.24	1.38
S. Manchester, -	K. B. Loomis, -	5.47	2.28	3.40	5.15	1.81	1.20
Vernon, -	E. H. Lathrop, -	5.10	3.06	7.02	4.94	2.30	1.48
Mansfield (Storrs), -	Expt. Station, -	5.60	2.77	3.25	5.20	1.40	1.09
N. Franklin, -	C. H. Lathrop, -	3.86	0.96	3.21	2.74	2.03	1.32
Lebanon, -	J. H. Tucker, -	5.93	1.59	2.82	3.54	2.27	1.81
Lebanon, -	Edw. Hoxie, -	5.71	1.46	3.56	3.11	1.90	1.77
Colchester, -	S. P. Willard,* -	5.05	—	3.33	3.91	1.34	1.28
New London, -	Weather Bureau,* -	4.07	2.46	2.57	3.45	2.04	0.98
Lake Konomore, -	N. London Wat'r Wks.* -	5.31	2.18	2.76	3.22	1.51	1.19
Voluntown, -	Rev. E. Dewhurst,* -	4.58	1.97	3.06	3.37	2.83	2.36
Brooklyn, -	A. B. Webb, -	4.24	2.59	2.47	3.97	2.00	0.00
Pomfret Landing, -	E. T. White, -	4.19	3.65	3.10	2.85	2.48	1.34
Putnam, -	Jerome Warren, -	4.97	3.90	2.60	3.72	—	—
N. Woodstock, -	L. H. Healy,* -	6.80	3.20	4.70	2.50	2.40	0.00
N. Grosvenor Dale, -	C. H. Truesdell,* -	6.00	3.79	4.54	5.00	1.80	1.52
Average, -	- - - - -	5.31	2.65	3.80	4.35	2.17	1.16
							19.67

* New England Meteorological Society Observer.

TABLE 17.
Meteorological Summary for 1892.

OBSERVATIONS MADE AT THE STATION BY E. A. BAILEY AND S. H. BUELL.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, -	30.69	30.71	30.49	30.61	30.44	30.40	30.50	30.23	30.44	30.92	30.46	30.56	30.54	—
Lowest barometer, -	29.27	29.15	29.28	29.56	29.53	29.61	29.70	29.78	29.57	29.52	29.63	29.49	29.51	—
Mean barometer, -	30.01	30.14	29.93	30.03	29.99	29.95	30.04	30.01	30.16	29.98	30.05	30.02	30.03	—
Highest temperature, -	58.2	43.8	55.0	75.9	80.5	90.8	92.0	88.5	78.0	74.5	63.5	46.5	70.6	—
Lowest temperature, -	2.5	1.9	8.1	22.0	34.2	43.3	43.5	50.0	39.5	29.8	15.0	1.0	23.7	—
Mean temperature, -	25.5	26.9	29.9	44.9	53.6	67.0	69.2	67.4	59.1	48.5	37.6	25.5	46.3	—
Relative humidity, -	—	—	—	65.6	81.1	79.8	76.6	86.1	79.3	76.2	—	—	77.8	—
Total precipitation, -	4.91	1.60	3.00	.70	5.60	2.77	3.25	5.20	1.40	1.09	5.41	1.35	—	36.28
Number of days with precipitation of .01 inches or more, }	9	7	7	5	15	12	9	10	4	5	11	6	—	100
Number of clear days, -	7	9	12	10	4	6	13	9	19	12	11	12	—	124
Number of fair days, -	12	6	10	14	13	17	12	11	5	9	7	10	—	126
Number of cloudy days, -	12	14	9	6	14	7	6	11	6	10	12	9	—	116
Total movement of wind in miles, }	8,500	7,737	11,721	8,312	6,618	5,554	5,008	4,361	4,000	5,534	5,565	6,832	—	—
Maximum velocity, -	60	50	60	42	32	36	36	30	40	36	48	50	—	—

EFFECT OF NITROGENOUS FERTILIZERS UPON THE PERCENTAGES OF PROTEIN IN GRASSES AND GRAINS.

BY CHAS. D. WOODS.

In the Annual Report of this Station for 1891* attention was called to the small proportions of protein in our feeding stuffs. Taken as a whole, they have a relative excess of the materials which serve the body of the animal for fuel and for making fat, while the protein compounds, which build muscle, tendon and other tissue, are relatively deficient. The same point is brought out in an article by Prof. W. O. Atwater in the Experiment Station Record, Vol. III., p. 676, from which the following is quoted:

"In the better cultivated parts of Europe much larger crops are generally grown than is usual with us. The statistics at hand imply that the grasses and forage crops at least are much richer in nitrogen.

Comparison of Proportions of Protein in American and European Grasses and Clover.

SPECIES.	AMERICAN.		EUROPEAN.	
	Specim's Analyzed	Protein in Water-free Substance.	Specim's Analyzed	Protein in Water-free Substance.
		Per cent.		Per cent.
Timothy (<i>Phleum pratense</i>), - -	56	8.0	7	11.8
Orchard grass (<i>Dactylis glomerata</i>),	4	9.6	7	14.9
Blue grass (<i>Poa pratensis</i>), - -	18	11.8	6	11.6
Red clover (<i>Trifolium pratense</i>), -				
Pasture, - - - - -	—	—	18	25.5
In bud, - - - - -	2	17.8	11	20.5
Early in blossom, - - - - -	—	—	19	17.9
Full blossom, - - - - -	5	15.7	46	16.1
Nearly ripe, - - - - -	4	14.2	4	16.7

* Page 168.

"In the preceding table are given the average percentages of protein in three common species of grasses and in red clover.

"The American figures are from the compilation of American analyses by Messrs. Jenkins and Winton.* The European are from *Dietrich und König's Zusammensetzung und Verdaulichkeit der Futtermittel* (second edition, 1891). In averages of analyses collated from such widely diverse sources it would be wrong to expect regularity, but taken together they show a most noteworthy advantage of the European products as compared with the American. The data at hand do not suffice for satisfactory comparisons of other grasses and legumes. Those for wheat show a preponderance of nitrogen in that from the better cultivated regions of continental Europe as compared with that from the United States. The comparative averages for the other grains, of which the number of analyses is smaller, are irregular.

"It looks very much as though we have by careless culture and insufficient manuring of our grasses and other forage crops, if not of our grains, for years been gradually breeding varieties poor in nitrogen, while in Europe the opposite course has been pursued. Certain it is that our grasses often contain smaller percentages of protein than are found in the best qualities of corn-stalks, and even straw."

For four years the Station has conducted experiments on the effects of nitrogenous fertilizers in different amounts and combinations upon the growth of plants and their capacity to gather their nitrogen from natural sources. Descriptions of these experiments made in 1892 may be found in the article on the Effects of Nitrogenous Fertilizers Upon Grasses, page 36 of this Report, and in the accounts of coöperative field experiments with fertilizers beyond.

In connection with these experiments, a study of the proximate composition of the products grown was undertaken, so far as time would allow, in order to study among other things the effects of different fertilizers upon the percentage composition and upon the total yield of nutritive ingredients of the plant, *with especial reference to the effect of nitrogenous fertilizers upon the percentages and amounts of protein.*

The effects upon the percentages of protein in the plants as distinguished from the total amounts of protein in the crop are here discussed.

* Experiment Station Bulletin, No. 11. Office of Experiment Stations, U. S. Department of Agriculture.

The results of analyses of the crops experimented upon seemed to point out that the percentages of protein were very decidedly affected by the quantities of nitrogen supplied in the fertilizer, and it is from the results of these experiments that we have been urging upon farmers greater attention to the culture and manuring of field crops than they have ordinarily received. The results of these analyses have been printed in previous Reports* which give the proximate analyses of the crops, and in many instances the yields per acre of the nutritive ingredients. These experiments, with scarcely an exception, have told the same story: *The addition of nitrogen in the fertilizer increased the percentages of protein in the crop.* In order to show concisely the results of our experiments upon this question, there is given in table 18, which follows, a summary of the results obtained by the use of nitrogenous fertilizers in varying quantities. Of course, the unevenness of the soils, some of which were deficient in nitrogen while others apparently had it in store in sufficient abundance for the needs of the plant, would make the deductions from any single experiment unreliable, but the average results of such a large number as are here reported upon, justify more or less definite conclusions.

In the table there is given in the first column the number of experiments upon which the averages are based. The remaining columns give the percentages of protein in the crop when grown without fertilizers, with mixed minerals (phosphoric acid and potash), and with mixed minerals to which nitrogenous fertilizers were added in quantities to supply 25, 50 and 75 pounds of nitrogen per acre.

* Report of this Station, 1889, pages 127-178; 1890, pp. 44-56 and 93-111; 1891, pp. 29-40; this Report.

TABLE 18.

Effect of Nitrogenous Fertilizers upon the Percentages of Protein (Nitrogen $\times$ 6.25) in Grasses and Grains.

KIND OF CROP.	No. of Experiments.	Without Fertilizers.	Phosphoric Acid and Potash (Mixed Minerals).	Mixed Minerals and 25 lbs. Nitrogen per acre.	Mixed Minerals and 50 lbs. Nitrogen per acre.	Mixed Minerals and 75 lbs. Nitrogen per acre.
		%	%	%	%	%
White flint corn, - - - -	3	13.1	12.5	12.5	13.3	14.4
Yellow flint corn, - - - -	3	11.6	9.9	10.2	10.5	11.8
Yellow flint corn, - - - -	3	12.1	11.4	12.7	12.2	13.2
Yellow flint corn, - - - -	3	11.6	10.9	12.7	11.8	12.0
Yellow flint corn, - - - -	3	12.5	9.7	9.7	9.7	10.1
Yellow flint corn, - - - -	3	11.4	10.9	10.3	10.9	11.0
Yellow flint corn, - - - -	1	11.0	10.9	11.0	—	11.9
Average, - - - -	19	11.7	10.6	11.1	11.0	11.7
White flint stover, - - - -	3	10.1	8.8	8.1	9.3	11.3
Yellow flint stover, - - - -	3	8.3	6.1	6.2	5.9	7.3
Yellow flint stover, - - - -	3	7.1	7.1	8.2	7.9	8.7
Yellow flint stover, - - - -	3	8.9	6.1	7.4	7.4	7.5
Yellow flint stover, - - - -	3	7.9	4.6	4.7	4.6	5.0
Yellow flint stover, - - - -	3	6.4	5.1	5.0	4.7	5.5
Yellow flint stover, - - - -	1	7.0	5.6	6.6	—	8.1
Average, - - - -	19	7.6	5.8	6.4	6.1	7.0
Oats, - - - -	3	13.7	14.3	14.7	15.2	15.5
Oats, - - - -	2	16.0	15.9	16.0	16.1	17.1
Average, - - - -	5	14.9	15.1	15.4	15.7	16.3
Oat straw, - - - -	3	8.7	6.0	5.4	5.8	6.3
Oat straw, - - - -	2	5.5	4.6	4.0	4.5	5.6
Average, - - - -	5	7.1	5.3	4.7	5.2	6.0
Mixed grasses, - - - -	2	7.3	8.2	8.0	8.2	9.2
Mixed grasses, - - - -	2	6.9	7.0	7.2	8.8	9.5
Mixed grasses, - - - -	1	7.7	10.9*	7.7	9.3	10.6
Average, - - - -	5	7.3	7.6	7.6	8.8	9.8
Orchard grass, - - - -	1	8.4	9.6	8.8	—	9.6
Orchard grass, - - - -	1	8.4	8.2	11.5	—	15.5
Average, - - - -	2	8.4	8.9	10.2	—	12.6
Timothy, - - - -	1	9.2	9.1	9.1	—	10.4
Timothy, - - - -	1	6.8	6.3	7.1	—	10.7
Average, - - - -	2	8.0	7.7	8.1	—	10.6
Tall red-top, - - - -	1	—	—	8.8	—	13.3
Tall red-top, - - - -	1	—	—	7.6	—	9.3
Average, - - - -	2	—	—	8.2	—	11.3
Smaller red-top, - - - -	1	—	—	8.4	—	11.9
Fowl meadow grass, - - - -	1	—	—	12.1	—	14.9
Rye grass, - - - -	1	—	—	10.9	—	12.6
Meadow fescue, - - - -	1	—	—	7.5	—	10.9
Kentucky blue grass, - - - -	1	—	—	12.9	—	15.4
Oat grass, - - - -	1	—	—	10.5	—	11.9
Brome grass, - - - -	1	—	—	10.6	—	11.0
Hungarian grass, - - - -	1	—	5.8	7.1	—	7.9
Average of grasses, - - - -	19	—	—	8.8	—	10.9

* Largely clover; omitted from average.

In the case of corn, as will be noted, the percentages of protein in the crop from the unfertilized plots were in every case nearly as large as that from the plot receiving the largest quantities of nitrogenous fertilizers, and in one instance the protein was 2.5 per cent. higher in the crop from the unfertilized than in that from the fertilized plots. The grain grown on the plots without fertilizers in nearly every case failed to mature properly, and the resulting corn consisted largely of "nubbins" and soft ears. The results of the analyses of "good" or merchantable corn and "poor" corn (soft ears and "nubbins") * indicate a great difference in the percentages of protein. The average of nine samples of "good" corn gave 11 per cent. protein, while the analyses of the "poor" corn from the same plots gave 12.5 per cent. protein. The percentages of protein in the "poor" corn exceeded that in the "good" by an average of 1.5 per cent., varying from a minimum of .75 to a maximum of 2.3 per cent. This is believed to be the explanation of the high percentages of protein in the corn grown without fertilizers. It is a well established fact that immature plants contain relatively a larger amount of protein than do mature, and in the majority of instances, the plants grown without fertilizers made poor development. Apparently the undeveloped plant has relatively little starch and other carbohydrates. On this account the effects of the nitrogen are best observed in comparing the produce from the mixed minerals plots (superphosphate and muriate of potash) with that from the plots which received nitrogen in addition to the mixed minerals.

The differences between the crops grown with mixed minerals alone and mixed minerals plus 25 pounds of nitrogen per acre, were in some cases slight. It may be that in these cases the soil contained enough available nitrogen for the needs of the plant, and that the addition of the small quantity did not suffice to produce any marked effect upon the composition of the crop, since, in these cases, it added so greatly to the total yield † that the effect would not be visible in percentage composition. There may be still another reason for the apparent slight increase in the percentage of protein with the increase in the nitrogen applied, namely, that the samples analyzed did not accurately represent

* Report of this Station 1890, pages 26-28.

† By reference to the places cited in a foot note on the previous page, where the results of this work have been printed in detail, it will be seen that the yield of protein per acre was quite markedly increased by the addition of 25 pounds of nitrogen.

the whole crop. The results of the analyses of corn, grain and stover, are less satisfactory, and particular instances are less reliable than in the case of the other crops. After the analyses of quite a number of corn experiments had been made, with results somewhat difficult to interpret, a study was made on the sources of error in obtaining field samples,* with the result that duplicate samples from the same plot, even when taken with great care, showed very considerable variations in composition. In the case of such a plant as corn, where naturally only a comparatively small number of plants would enter into the sample, the variations due to errors in obtaining samples were found to be considerably greater than in the case of plants like grass or oats, where a much larger number of plants would be taken. It would seem, however, that the number of trials averaged must be sufficient to make the inferences reasonably reliable for the conditions under which the experiments were made.

SUMMARY.

The results of 73 experiments upon the effect of nitrogenous fertilizers upon the protein of the crop have been given in detail in the present and earlier Reports of the Station,† and are concisely summed up in the following table:

Results of Analyses showing Relation between Nitrogen applied in Fertilizers and Protein (Nitrogen $\times$ 6.25) found in Resulting Crops.

KIND OF CROP.	No. of Experiments.	Phosphoric Acid and Potash (Mixed Minerals).	Mixed Minerals and 25 lbs. Nitrogen per acre.	Mixed Minerals and 50 lbs. Nitrogen per acre.	Mixed Minerals and 75 lbs. Nitrogen per acre.
		%	%	%	%
Corn (grain), - - - - -	22	10.9	11.3	11.4	12.1
Oats (grain), - - - - -	5	15.1	15.4	15.7	16.3
Corn stover, - - - - -	22	6.2	6.6	6.6	7.6
Oat straw, - - - - -	5	5.3	4.7	5.2	6.0
Mixed grasses, - - - - -	5	7.6†	7.6	8.8	9.8
Orchard grass, - - - - -	2	8.9	10.2	—	12.6
Timothy, - - - - -	2	7.7	8.1	—	10.6
Red-top, - - - - -	3	—	8.3	—	11.7
Seven other pure grasses, - - -	7	—	10.2	—	12.1

* Report of the Station, 1890, pages 120-135.

† See foot note, page 62.

‡ Included more clover than other plots.

The results as shown in the table need no explanation, as the figures tell the story so plainly. In each case, except that of oat straw, the percentages of protein were greater when nitrogen was applied in the fertilizers than when it was not. In general, the percentages of protein increased with the amount of nitrogen applied, though, in most cases, the application of the largest amount of nitrogen seemed to have the most marked effect upon the protein of the crop.

PRACTICAL CONCLUSIONS.

The Station has for years been urging upon the attention of farmers that the value of nitrogenous feeding stuffs is not sufficiently appreciated. The progress of exact experiment is bringing this fact out more and more clearly. Thus the experiments on the effects of fodder upon the production of milk, lately made in some of our Stations, emphasize most forcibly the need of rations much richer in protein than most farmers feed. Similar and still more striking results have been found in an extended series of experiments on feeding cows for milk and steers for fattening, conducted on a number of farms in Prussia.

Our crops contain a large excess of the materials which serve as fuel, while the protein compounds which make muscle, bone, and milk are relatively wanting. The farmer is primarily responsible for this state of affairs, and must be the one to take the first steps to amend it. The protein needed for the use of the stock kept on the farm may be obtained in one of three ways. It may be purchased in the form of concentrated feeds, such as wheat bran, oil meals, etc.; it may be obtained by growing the legumes which are able to obtain nitrogen directly from the air and convert it into protein; or it may be obtained by breeding and importing varieties of grains and grasses richer in nitrogen than those now cultivated. While it is probable that the feeder must, for the present, continue to buy some of the protein which his animals need, still by care in selection of crops, and by growing plants richer in nitrogen, much more protein may be produced on the farm itself. This protein is needed for fodder in order to make leaner meat, and more of it, and more milk at less cost. The nitrogen not transformed into meat or milk makes rich manure for grasses, grains and other crops, and the rich manure helps to bring larger crops, and crops richer in protein.

RESULTS OF EXPERIMENTS WITH FERTILIZERS ON DIFFERENT CLASSES OF SOILS.

BY C. S. PHELPS.

The object of this paper is to summarize the results of about 90 soil test experiments with fertilizers, conducted in this and other New England States during the past 15 years. The results of the experiments have been studied with reference to the classes of soils, for the purpose of ascertaining the relations, if any, between the kinds of soils and their deficiencies. The results have been summarized and tabulated in two groups: (1) Soils ranging from sandy to loam, and (2) soils ranging from heavy loams to heavy clays. Many of the experiments could not be included in either of these groups owing to the absence of sufficient data, or the variable character of the soil. In such cases the experiments have been omitted from the tabulations. At the close of this article will be found a series of tables giving the results in detail for the different classes of soils.

EXPERIMENTS MADE DURING THE YEARS 1878-81.

In the year 1877 the Director of this Station, then Director of the Connecticut Agricultural Experiment Station, inaugurated a series of field tests with fertilizers by farmers and scientific men in different parts of the country. The experiments were largely on corn, although potatoes, turnips, oats and other crops were included. They were continued under his direction during a series of years, and in a number of instances are still being carried on. The purpose of the experiments as then stated is given in the following extract from the report of that Station for 1876:

“One of the fundamental results of the vast amount of work done in field experiments with fertilizers is the clear demonstration that soils vary greatly in their capabilities of supplying food to crops, that different ingredients are deficient in different soils, and that the teachings of any given experiment are in the main applicable only to the particular kind of soil on which it is made.

“For farmers who have not their own experience, or that of others in like circumstances, to guide them, the most sensible method for determining what are the deficiencies of their soils, and how they will be the most economically supplied to given crops, is to try experiments on a small scale; to put the question to the soil with different fertilizing materials and obtain its reply in the crops produced.”

These experiments were conducted over a wide range of country, although the greater part were in the New England States, New York, and New Jersey. They were carried out in accordance with printed directions sent out by Prof. Atwater. Many were evidently conducted with care and thoroughness, while others were of little value. Those showing discrepancies in the work, or abnormal results due to soil variation, weather, or other causes, have been discarded, and only those used that appeared to furnish results of value. For the purpose of this article, only the experiments made in New England have been included.

Reports on these experiments and tabulations giving results in detail will be found in the reports of the Connecticut Board of Agriculture for the years 1878, 1879, 1880, and 1881, and also in pamphlet form as reported for the U. S. Department of Agriculture in 1883.

The following is taken from the latter report, and indicates some of the difficulties met with and an estimate of the value of the work, by Prof. Atwater, after five years' experience with this class of experiments:

“Many of the reports have no decided story to tell, and some none at all, except failure everywhere. Some were on land so rich that the action of the fertilizers was obscured by the stores of plant-food in the soil; others on soil seemingly in such physical condition that no artificial supply of plant-food could make it fertile. The most serious difficulty of all has been found in the unevenness of the soil. The plots on one side were dryer than on the other; or one plot was on old sod ground and another had been lately cultivated, and showed the effects of previous manuring; while some were irregular for reasons upon which the reports throw no light. On the whole, the general character of the work, as evidenced by the reports, is a most forcible illustration of the truth that among our farmers there is an amount of intelligence and ability which is not appreciated either by themselves or by

the community at large, but which is capable of making, indeed is making, a very rapid advance in the intellectual character of our agriculture."

EXPERIMENTS MADE DURING THE YEARS 1888-91.

Since the organization of the Storrs School Station, in 1888, similar soil test experiments with fertilizers have been carried out. The general plan* is the same as for those conducted in this and other States during the years 1878-81. The work, however, has been more closely under the direction of the Station; either the Agriculturist or his assistant having supervision of the more important operations, such as the laying out of plots, application of fertilizers, harvesting and weighing the crop, etc.

The following from a previous report gives the object and purpose of the experiments:

1. To work directly upon farm lands in different parts of the State, and to aid the owners in learning the deficiencies of their soils and the requirements of their crops.

2. To help farmers in becoming familiar with the forms and action of fertilizing materials containing phosphoric acid, potash, and nitrogen, and to better understand their profitable use.

3. To encourage a spirit of investigation, and thus to gradually develop a number of farm experimenters, whose work will be useful not only to themselves, but in a large degree to their communities and to the agriculture of the State.

These experiments are, perhaps, of greater value to the farmer who conducts them than to any one else; not only does he gain a knowledge of particular soils, but at the same time he is led to appreciate the great need and importance of scientific work. Through discussions in Granges and Farmers' Clubs he also succeeds in interesting many others. The value of the tests and their application become more general where they are continued over a period of years.

THE PLAN OF SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in

* See Report of this Station, 1890, pp. 87-93.

standard commercial forms, and consisted of nitrate of soda, dissolved bone-black, muriate of potash, and land plaster.

AVERAGE RESULTS WITH SOIL TESTS ON HEAVY AND LIGHT SOILS.

In table 19, which follows, will be found the average yields of shelled corn for 31 experiments conducted in various parts of New England during the years 1878-81, and 20 experiments made in this State under the charge of the Station in 1888-91. In each case the experiments have been divided into two groups—first, soils ranging from sandy to loam (light soils), and second, from loam to heavy clay (heavy soils).

TABLE 19.

Average Yields of Shelled Corn per Acre on Heavy and Light Soils.

No. of Plot.	KIND OF FERTILIZERS.	1878-1881.				1888-1891.			
		Fertilizers.		Av'g 20 Expts, Light soils.	Av'g 11 Expts, Heavy soils.	Fertilizers.		Av'g 12 Expts, Light soils.	Av'g 8 Expts, Heavy soils.
		Weight.	Cost.			Weight.	Cost.		
		Lbs.	\$	Bu.	Bu.	Lbs.	\$	Bu.	Bu.
o	Nothing, - -	—	—	25.5	20.8	—	—	16.9	15.3
A	Nitrate of Soda, -	200	7.50	33.3	24.7	160	3.96	22.8	19.5
B	Dis. Bone-black, -	300	5.25	35.1	35.2	320	4.40	19.5	27.2
C	Muriate of Potash, -	200	4.50	34.3	25.9	160	3.48	25.9	20.4
D	{ Nitrate of Soda, -	150 }	10.88	41.4	38.8	160 }	8.48	26.8	30.4
	{ Dis. Bone-black, -	300 }				320 }			
E	{ Nitrate of Soda, -	150 }	10.13	35.5	25.9	160 }	7.52	34.7	19.3
	{ Muriate of Potash, -	200 }				160 }			
F	{ Dis. Bone-black, -	300 }	9.75	40.1	38.8	320 }	8.00	28.0	32.9
	{ Muriate of Potash, -	200 }				160 }			
G	{ Nitrate of Soda, -	150 }	15.38	50.3	41.0	160 }	12.00	38.4	33.2
	{ Dis. Bone-black, -	300 }				320 }			
H	{ Muriate of Potash, -	200 }	.80	27.5	26.4	160 }	1.70	21.2	18.5
	{ Plaster, - -	200 }				400 }			
o	Nothing, - -	—	—	31.9	27.6	—	—	18.2	22.3

In table 20, on the next page, are given the average results from the use of the different fertilizing ingredients (nitrogen, phosphoric acid, and potash).

These figures were obtained by averaging the yields on all of the fertilized plots (four) receiving nitrogen, and on all (four) having no nitrogen. The difference between these two averages was considered to be the gain or loss due to the use of nitrogen. The gain or loss from the use of phosphoric acid and potash was considered in a similar way. By comparing the gain or loss

from the use of nitrogen, with the gain or loss from the use of phosphoric acid and potash, it becomes evident which ingredient had the ruling effect in each experiment.

TABLE 20.

Average Yields of Shelled Corn per Acre from the Use of the Different Fertilizing Ingredients.

		Number Experiments.	Nitrogen.			Phosphoric Acid.			Potash		
			Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
Light Soils	1878-81,	17	38.7	33.8	4.9	39.5	32.9	6.6	38.6	34.0	4.6
	1888-91,	12	30.8	24.5	6.3	27.9	27.8	0.1	31.8	23.0	8.8
	1878-91,	29	35.4	29.9	5.5	34.7	30.7	4.0	35.8	29.5	6.3
Heavy Soils	1878-81,	10	32.5	32.0	0.5	38.2	24.7	13.5	32.6	31.6	1.0
	1888-91,	18	25.6	26.8	-1.2	30.9	19.8	11.1	26.5	26.1	0.4
	1878-91,	18	29.4	29.2	0.2	35.0	22.5	12.5	29.9	29.2	0.7

In the earlier experiments (1878-81) on sandy to loam soils, phosphoric acid had the leading effect in eight experiments, potash in five, nitrogen in three, and nitrogen and potash were alike in one. In the later experiments (1888-91) the lighter soils were more generally benefited by potash fertilizers. Of the twelve experiments on this class of soils all but two showed a marked increase of crop where potash was used; in only one case was there any considerable increase from the use of phosphoric acid, while with nitrogen all but one gave more or less increase.

In the earlier experiments, on heavy loam to heavy clay soils, phosphoric acid had the leading effect in eight experiments, potash in one, and potash and nitrogen were alike in one; while for eight experiments made during 1888-91 on this class of soils, every one showed considerable increase of crop from the use of phosphoric acid, only two gave any increase with potash, while with nitrogen there was no increase of account in any of the experiments.

The results of the earlier experiments on light soils seem to differ somewhat from those made in Connecticut during the past four years. In the earlier experiments, in the majority of cases, phosphoric acid gave the most marked increase of crop, while in several potash produced the greater yield. These experiments

indicate that such soils, as a whole, are more apt to be lacking in two or three of the essential ingredients (nitrogen, phosphoric acid, and potash) than are the heavier soils. In the case of experiments made on Connecticut soils of this class since the year 1888 the results are somewhat different. The crops grown on light soils were in nearly all cases greatly increased by the use of potash, or nitrogen, or both, while in only one case was there any considerable increase from the use of phosphoric acid. *The experiments thus far made indicate that for corn on the lighter soils of the State, fertilizers containing a large proportion of potash are needed to give the best results.* •

On the other hand, in the case of the heavy soils, nearly all of the experiments recorded indicate a lack of phosphoric acid. With only one or two exceptions, phosphoric acid has greatly increased the yield, especially of grain, while a much smaller increase has resulted from the use of either potash or nitrogen.

The results thus far reached point to the conclusion that for corn, fertilizers with relatively large proportions of phosphoric acid produce the best results on heavy, clayey soils.

It is of interest also to notice the effect of nitrogen on the two classes of soils. In the majority of cases, on the light soils, corn was considerably benefited by nitrogen. The average increase on the fertilized plots having nitrogen over those without, in 29 experiments on light soils, was 5.5 bushels. In the 18 experiments made on the heavy soils, nitrogen gave an increase above two bushels in only three experiments, and the average yield per acre was only two-tenths of a bushel more with nitrogen than on the plots where no nitrogen was applied. The results seem to indicate that soluble nitrogen compounds, like nitrate of soda, cannot be economically used for corn on heavy soils in this region.

EXPERIMENTS ON POTATOES.

A series of experiments similar to those made on corn during the years 1878-81, were also made on potatoes. The kind of fertilizers used and the general plan were the same in the two cases.

The results of fourteen of these experiments have been tabulated and divided into classes according to the character of the soils, the same as for the corn experiments. The number of experiments, however, is too small for making general deductions, although the results appear to be worthy of consideration, as they tend to corroborate those obtained on corn.

TABLE 21.
Average Yields in Potato Experiments (1878-81).

No. of Plot.	FERTILIZERS PER ACRE.			Light Soil Exp't.	Heavy Soil Exp't.
	KIND.	Weight.	Cost.		
				Bu. per Acre.	Bu. per Acre.
		Lbs.	\$		
o.	Nothing, - - - - -	—	—	65.7	97.9
A.	Nitrate of Soda, - - - - -	200	7.50	79.0	98.5
B.	Dissolved Bone-black, - - - - -	300	5.25	91.1	132.1
C.	Muriate of Potash, - - - - -	200	4.50	96.5	118.7
D.	{ Nitrate of Soda, - - - - -	150	10.88	91.5	147.0
	{ Dissolved Bone-black, - - - - -	300			
E.	{ Nitrate of Soda, - - - - -	150	10.13	80.1	105.7
	{ Muriate of Potash, - - - - -	200			
F.	{ Dissolved Bone-black, - - - - -	300	9.75	103.2	170.6
	{ Muriate of Potash, - - - - -	200			
G.	{ Nitrate of Soda, - - - - -	150	15.38	138.9	193.3
	{ Dissolved Bone-black, - - - - -	300			
	{ Muriate of Potash, - - - - -	200			
H.	Plaster, - - - - -	200	.80	62.4	117.3
oo.	Nothing, - - - - -	—	—	—	94.0

TABLE 22.
Average Yields of Potatoes per Acre from the Use of Different Fertilizing Ingredients.

KIND OF SOIL.	Nitrogen.			Phosphoric Acid.			Potash.		
	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
Light Soils, -	Bu. 98.9	Bu. 92.9	Bu. 6.0	Bu. 106.2	Bu. 85.2	Bu. 21.0	Bu. 106.2	Bu. 85.0	Bu. 21.1
Heavy Soils, -	128.4	121.7	6.7	150.2	98.9	51.3	137.9	112.2	25.7

In table 21 above will be found the average yields per acre on the various plots, and the average yields, together with the gain or loss, from the use of the different fertilizing ingredients.

In the case of the lighter soils only five experiments are reported. In most cases all three ingredients (nitrogen, phosphoric acid, and potash) gave considerable increase in the yield, while the average gain from the use of phosphoric acid was the same as with potash.

With the heaviest soils, in nearly all cases, there was an increase in the yield from each of the essential ingredients, but the increase from the use of phosphoric acid was double that from the use of potash. *These experiments indicate that for potatoes as well as for corn, heavy soils of a clayey character usually need to be supplied with fertilizers containing large amounts of available phosphoric acid, while potash may be more sparingly used.*

EXPERIMENTS BY THE HATCH STATION, MASSACHUSETTS.

A series of soil tests on corn have been carried on for three years in Massachusetts, under the direction of Prof. William Brooks, of Amherst. Nearly all of these were made on light soils, varying from sandy loam to loam. Wherever serious variations appeared, or abnormal yields have occurred, or when the character of the soil could not be determined from the data given, the experiments have not been used for the calculations herewith. Fifteen experiments are here tabulated, all of which were on the lighter soils. The average yields per plot and the average results with nitrogen, phosphoric acid, and potash, are given in the table which follows, for the fifteen experiments on light soils.

TABLE 23.

Experiments on Corn in Massachusetts. Light Soils.

No. of Plot.	FERTILIZERS PER ACRE.		15 Experiments Shelled Corn, per Acre.	BUSHELS PER ACRE WITH DIFFERENT FERTILIZERS.					
	KIND.	Weight.		Nitrogen.					
				Plots With.	Plots Without.	Gain With.			
		Lbs.	Bu.						
O.	Nothing, - - -	—	24.0	36.9	32.5	4.4			
A.	Nitrate of Soda, - -	160	31.1						
B.	Dissolved Bone-black, -	320	29.2	Phosphoric Acid.					
O.	Nothing, - - -	—	25.6	Plots With.	Plots Without.	Gain With.			
C.	Muriate of Potash, -	160	34.8						
D.	Nitrate of Soda, - -	160	34.0	36.8	32.5	4.3			
	Dissolved Bone-black, -	320							
E.	Nitrate of Soda, - -	160	37.2				Potash.		
	Muriate of Potash, -	160							
O.	Nothing, - - -	—	27.2						
F.	Dissolved Bone-black, -	320	38.8						
	Muriate of Potash, -	160							
G.	Nitrate of Soda, - -	160	45.2	Plots With.	Plots Without.	Gain With.			
	Dissolved Bone-black, -	320							
	Muriate of Potash, -	160							
H.	Plaster, - - -	160	27.0						
O.	Nothing, - - -	—	26.3	39.0	30.3	8.7			

It is of interest to note how generally these soils responded in the crop to the use of potash fertilizers. The results are in close accord with those obtained on soils of the same character in this State, and naturally lead to the conclusion that soils of this character are deficient in available potash and fail to produce good crops unless potash fertilizers are liberally supplied. It seems doubtful, however, if the same results would have followed on heavy, clayey soils, in Massachusetts especially, where such soils are in the granitic regions of the State. Only three of the experiments reported were on clayey soils. Of these two were in the Connecticut valley, in what is known as the old lake bottom of the Hadley meadows. All soils of this region, as far as tested, seem to show a lack of potash, and it is reasonable to conclude that the potash compounds, being more or less soluble, were not deposited from the water of this old lake. The other experiment is in the Housatonic valley, and is described as "alluvial, fine compact loam, with a tendency to clay." This soil is in a limestone region, which fact would probably account for the apparent lack of potash. Soils of this same geological formation, further south in Connecticut, have shown a similar lack of potash.

The soils of the granitic regions of both Connecticut and Massachusetts are quite similar in their origin and composition. As clay is formed from the decomposition of feldspar, from which it gets considerable potash, it is natural to conclude that such soils will not be as noticeably benefited by potash fertilizers as the lighter and more sandy soils. This conclusion is strengthened by experiments made in nearly all the New England States. In almost all experiments reported with corn on clayey soils of granitic origin, potash has caused but little increase of crop, while phosphoric acid has generally given a marked increase.

EXPERIMENTS AT THE RHODE ISLAND STATION.

The experiments reported from Rhode Island were made under the direction of the chemist of the Rhode Island Station, Dr. Wheeler. They are the soil test portions of special nitrogen experiments on corn. The experiments were undertaken for the purpose of studying the deficiencies of soils, and the relative effects of smaller and larger quantities of nitrogen. The special nitrogen portions of the experiments have not been used in this article.

TABLE 24.

Experiments on Corn in Rhode Island. Light Soils.

Number of Plot.	FERTILIZERS PER ACRE.			15 Experiments Shelled Corn, per Acre.	BUSHEL PER ACRE WITH DIFFERENT FERTILIZERS.				
	KIND.	Weight.	Cost.		Nitrogen.				
					Plots With.	Plots Without.	Gain With.		
		Lbs.	\$	Bu.					
0	Nothing, - - -	—	—	20.0	Phosphoric Acid.				
1	Nitrate of Soda, - - -	150	3.60	27.3	Plots With.	Plots Without.	Gain With.		
2	Dissolved Bone-black, - - -	350	4.38	31.3					
3	Muriate of Potash, - - -	130	3.06	30.5	37.1	30.5	6.6		
4	Nitrate of Soda, - 150 }	500	7.98	39.1				Potash.	
	Dis. Bone-black, - 350 }				280			6.66	32.8
5	Nitrate of Soda, - 150 }	480	7.44	38.3					
6	Muriate of Potash, 130 }			630	11.04	42.1			
	Nitrate of Soda, - 150 }	35.9	32.6			3.3			
7	Dis. Bone-black, - 350 }						35.9	32.6	3.3
	Muriate of Potash, 130 }								
00	Nothing, - - -	—	—	24.5					

Nearly all the experiments were made on the lighter class of soils, varying from sandy to loam. In a few cases the data indicated that the soils were of a clayey character, and these were omitted from the tabulations.

From the results on this class of soils it will be seen that no one ingredient was beneficial to the exclusion of others. Phosphoric acid is seen to have the leading effect on the crop, when the results of the three ingredients are compared. This does not corroborate the results on similar soils in Connecticut and Massachusetts, and goes to show that such soils are not likely to be uniform in their deficiencies.

Many of the experiments were conducted for two successive years on the same soil. In such cases the benefit derived from any single ingredient would be more striking the second season, and hence the average increase from phosphoric acid would probably not have been as great had the experiment been made on a larger number of soils. It would be of interest also to ascertain the results on soils of a clayey nature to compare with those on the lighter soils. From the general similarity of the

soils in this State and Rhode Island it would seem probable that the heavier soils would indicate similar needs. In fact, in one or two experiments reported, made on clayey soils, phosphoric acid did produce the most marked effect, although the number of such experiments was not sufficient to warrant their tabulation.

THE VALUE OF THE EXPERIMENTS AND PRACTICAL DEDUCTIONS.

THE VALUE OF SOIL TESTS.

Coöperative field experiments with fertilizers by farmers have become a part of the work of quite a number of the Experiment Stations of the country. They have an especially important place in these States where commercial fertilizers are extensively used. The object aimed at is to study the soils of different regions, learn their deficiencies, and find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical manner.

The wide variations in soils indicate that the results of any one experiment are applicable only to the particular soils experimented upon, or to soils of a similar character. Where this class of experimenting is wholly on the Station farm, the work has only a local value, and in order to make the experiments of highest value to the farmers of the State they must be carried out in a considerable number of places.

If the important operations, such as the selection of the field, the laying out of the plots, the planting, the application of the fertilizers, and the weighing and the harvesting of the crop, are under the supervision of an officer of the Station, there is no reason why the work cannot be carried out with the same degree of accuracy as at the Station.

UNIFORM SOILS AND THOSE DEFICIENT IN PLANT FOOD NEEDED.

For soil test experiments with fertilizers, poor and uniform soils should be selected. The object of such experiments is to learn what the soil can do of itself without the aid of added stores of plant food, and not to obtain, primarily, large crops.

If the soil lacks uniformity, or has an abundance of available plant-food, it will be impossible to judge how much of the growth is due to the plant-food in the fertilizer applied, and how much to that previously stored in the soil. Just here is the chief difficulty with field experiments, and one that tends to make the

results unreliable, unless the experiments are carried through a series of years. It is almost impossible to find a field of one or two acres that is uniform throughout. Soils vary greatly as to the amounts of available plant-food they contain; as to the relative amount of sand, clay, or humus present; as to fineness of texture, slope, powers of absorbing and retaining heat and moisture; and as to their powers of holding, in an available form, the fertilizing ingredients supplied. The subsoil also exerts considerable influence, especially in regulating the supply of moisture from the ground water.

DIFFERENCES IN SOILS.

Connecticut soils, being of the drift formation, are very complex in their make-up. Little can be learned with regard to their composition by a study of the rocks.

One soil may be made up largely of silica or quartz, while only a few rods away another may have been formed from feldspathic or potash containing rocks. Under these circumstances their natural fertility will vary greatly.

Chemical analysis of soils has not been found to be a satisfactory means of determining their fertility. While the analysis may show the composition of the particular sample analyzed, it fails to indicate the amount of plant-food that may be available to the crop.

In the so-called "soil tests" the plant acts as its own chemist. By applying the elements most commonly lacking, namely, nitrogen, phosphoric acid, and potash, singly and in combinations, to different plots of land, we enable the plants to draw from the soil the ingredients not supplied. If any of these constituents are already present in the soil in considerable quantities, the results in the crop will soon indicate it, and if any are lacking poor crops will result, until the needed fertilizing materials are supplied in an available form.

THE RELATIVE IMPORTANCE OF PHOSPHORIC ACID AND POTASH.

Many soils have supplies of phosphoric acid and potash that can be drawn upon, year by year, without materially lessening their productiveness. The soils of the Housatonic Valley, which have been experimented upon, seem to contain large quantities of phosphates and to be lacking in potash. In many parts of the State potash feldspar is abundant in the soils, and hence they are

generally quite well supplied with potash, although they show a decided lack of phosphoric acid. The beneficial effects of phosphoric acid are especially noticeable in the case of experiments made on the heavy soils in the towns of Lebanon, Putnam, Woodstock, and Pomfret, and this would probably prove true on soils of a similar character in other parts of the State. The work thus far done points strongly to the conclusion that heavy, clayey soils in Connecticut need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light sandy to loam soils are more generally, although not uniformly, helped by potash fertilizers.

IMPORTANCE OF NITROGEN.

Nitrogen holds in plant life and in the economy of the farm a very different position from phosphoric acid, potash, or lime. In the first place, it is the most costly ingredient of fertilizers; and, secondly, it is the most changeable and uncertain. It is supplied to our soils by commercial fertilizers, either as organic compounds, as in dried blood, fish, etc., as salts of ammonia, as sulphate of ammonia, or in the form of nitrates, but it is only in the form of nitrates, as in nitrate of soda, that plants can utilize it to any great extent. The other forms must be partly or entirely changed into nitrates before they become available to the plant. These changes take place after the fertilizer is added to the soil.

Nitrogen is readily lost in the drainage unless there is a crop on the soil that is in condition to utilize it. If the soil is left without a crop for any considerable length of time, much of the nitrogen will pass into the drainage in the form of nitrates. For the same reason, it should not be applied long before the crop is ready to use it. Nitrogen varies in its effects on corn in accordance with the kind of soil. The teaching of the experiments thus far made in Connecticut is that when nitrogen is used on the lighter class of soils the crop is most benefited. Such fertilizers as nitrate of soda and sulphate of ammonia can generally be used with profit on light loam soils. For some unexplained reason, however, soluble nitrogen compounds, such as nitrate of soda, rarely prove of much value for corn on heavy, clayey soils. Nitrogen is needed in order to get large crops of corn on these soils, and good results are generally obtained from the use of organic nitrogen in the form of slowly decaying vegetable matter.

On such soils the best financial results with corn are generally obtained by the use of yard manures as a source of nitrogen, and by commercial fertilizers to furnish the mineral ingredients that are lacking in the soil.

CONCLUSIONS.

Soils cannot be cultivated to the greatest profit without a knowledge of their deficiencies, as regards plant-food. Soil tests with fertilizers seem to be the best practical means for ascertaining these deficiencies in particular soils.

Heavy, clayey soils need to be supplied with large amounts of phosphoric acid in the fertilizers used, while light, sandy to loam soils are more generally, though not uniformly, helped by potash fertilizers.

The teachings of the experiments thus far made in Connecticut indicate that nitrogen is most beneficial on the light class of soils. Soluble fertilizers, as nitrate of soda and sulphate of ammonia, can generally be used with profit on light loam soils, but do not prove of much value for corn on heavy soils. For heavy soils nitrogen should be supplied in some organic form, as stable manure, dried blood, etc.

The wide differences found in soils afford a strong argument in favor of home mixed fertilizers. The special needs of different soils cannot be considered by the manufacturer who prepares his fertilizers for general use. The farmer may, however, prepare such mixtures as will meet both the deficiencies of his soil and the requirements of his crops.

NAMES AND ADDRESSES OF EXPERIMENTERS.

-
1. W. I. Bartholomew, Putnam, Conn.
 2. Prof. J. R. Farrington, Orono, Me.
 3. Edw. F. Smith, Tunbridge, Vt.
 4. W. I. Bartholomew, Putnam, Conn.
 5. J. W. Pierce, West Millbury, Mass.
 6. Zeno Benson, Bridgewater, Mass.
 7. E. N. Bissell, E. Shoreham, Vt.
 8. W. H. Pilbrook, North Hampton, N. H.
 9. Prof. W. H. Jordan, Orono, Me.
 10. W. I. Bartholomew, Putnam, Conn.
 11. H. F. Cox, Brooklyn, Conn.
 12. W. I. Bartholomew, Putnam, Conn.
 13. K. B. Loomis, S. Manchester, Conn.
 14. J. H. Tucker, Lebanon, Conn.
 15. L. H. Healey, N. Woodstock, Conn.
 16. Clifton Peck, Franklin, Conn.
 17. Storrs School Station, Mansfield, Conn.
 18. Jerome Warren, Putnam, Conn.
 19. James K. Toby, Calais, Vt.
 20. Hiram A. Cutting, Lunenburg, Vt.
 21. Prof. J. Farrington, Orono, Me.
 22. W. I. Bartholomew, Putnam, Conn.
 23. Edward M. Snow, Mansfield, Vt.
 24. Hiram A. Cutting, Lunenburg, Vt.
 25. A. N. Foster, Cabot, Vt.
 26. W. I. Bartholomew, Putnam, Conn.
 27. M. H. Dean, Falls Village, Conn.
 28. Z. E. Jameson, Irasburgh, Vt.
 29. Seth H. Rising, West Rupert, Vt.
 30. Chas. B. Gale, Plainfield, Vt.
 31. R. Bradley, Brattleboro, Vt.
 32. W. C. Atwood, Watertown, Conn.
 33. J. M. Manning, Taunton, Mass.
 34. Zeno Benson, Bridgewater, Mass.
 35. W. S. Simmons, Plymouth, Mass.
 36. C. Miller & Sons, Pomfret, Vt.
 37. J. M. Manning, Taunton, Mass.
 38. J. A. Chedel, So. Pomfret, Vt.
 39. Chester Sage, Middletown, Conn.
 40. J. D. Winslow, Pittsford, Vt.
 41. J. M. Manning, Taunton, Mass.
 42. Henry Gaylord, Cheshire, Conn.
 43. Chas. Fairchild, Middletown, Conn.
 44. J. H. Pann, Middleboro, Mass.
 45. A. C. Blake, New Britain, Conn.
 46. Frank Day, Danielsonville, Conn.
 47. M. H. Dean, Falls Village, Conn.
 48. M. H. Dean, Lime Rock, Conn.
 49. R. S. Hinman, Oxford, Conn.
 50. A. C. Blake, New Britain, Conn.
 51. Frank Day, Danielsonville, Conn.
 52. M. H. Dean, Falls Village, Conn.
 53. R. S. Hinman, Oxford, Conn.
 54. C. E. May, E. Woodstock, Conn.
 55. H. W. Sadd & Son, Wapping, Conn.
 56. F. L. Ensworth, Canterbury, Conn.
 57. S. P. Richmond, Freetown, Mass.
 58. Wm. S. Phillips, Jr., Marblehead, Mass.
 59. Dole Brothers, Shelburne, Mass.
 60. Pliny Moore, Worcester, Mass.
 61. Experiment Station, Amherst, Mass.
 62. Wm. S. Phillips, Marblehead, Mass.
 63. A. D. Copeland, Bridgewater, Mass.
 64. S. P. Richmond, Freetown, Mass.
 65. J. Bryden, Yarmouth, Mass.
 66. Pliny Moore, Worcester, Mass.
 67. Chas. F. Fowler, Westfield, Mass.
 68. Dole Brothers, Shelburne, Mass.
 69. Experiment Station, Amherst, Mass.
 70. G. L. Cooley, Sunderland, Mass.
 71. F. E. Clark, Wilbraham, Mass.
 72. Experiment Station, Kingston, R. I.
 73. H. E. Lewis, Hope Valley, R. I.
 74. G. B. Vaughn, Noose Neck, R. I.
 75. H. H. Geuchs, Lime Rock, R. I.
 76. E. F. Crowninshield, Abbott Run, R. I.
 77. Capwell & Tillinghast, Summit, R. I.
 78. A. A. Sherman, Daisville, R. I.
 79. E. K. Watson, Myatt Point, R. I.
 80. Experiment Station, Kingston, R. I.
 81. C. P. Chapman, Westerly, R. I.
 82. G. A. Tillinghast, Summit, R. I.
 83. E. F. Crowninshield, Abbott Run, R. I.
 84. H. E. Lewis, Hope Valley, R. I.
 85. T. A. H. Tefts, Jamestown, R. I.
 86. G. B. Vaughn, Noose Neck, R. I.
 87. J. R. Kinerson, Peacham, Vt.
 88. Zeno Benson, Bridgewater, Mass.
 89. John Labrun, Lee, Mass.
 90. Seth H. Rising, West Rupert, Vt.
 91. J. M. Manning, Taunton, Mass.

TABLE 25.

Effects of Individual Ingredients of Fertilizers on Corn and Potato Crops with Heavy Loam to Heavy Clay Soils.

Reference No.	LOCALITY.	NITROGEN.			PHOSPHORIC ACID.			POTASH.		
		Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).
	<i>Corn.</i>	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
	1878-81.									
1	Putnam, Ct., -	33.4	34.0	-0.6	44.2	19.6	24.6	33.8	33.5	0.3
2	Orono, Me., -	34.8	33.7	1.1	36.2	31.7	4.5	38.7	28.5	10.2
3	Tunbridge, Vt., -	33.8	32.5	1.3	34.4	31.9	2.5	33.1	33.1	0.0
4	Putnam, Ct., -	25.4	28.7	-3.3	41.4	7.4	34.0	25.6	28.4	-2.8
5	W. Millbury, Mass.,	8.5	9.7	-1.2	13.6	4.6	9.0	10.7	7.6	3.1
6	Bridgewater, Mass.,	25.7	21.6	4.1	28.6	18.8	9.8	21.4	25.9	-4.5
7	E. Shoreham, Vt.,	45.0	41.9	3.1	43.4	43.4	0.0	45.0	41.9	3.1
8	N. Hampt'n, N.H.,	65.9	59.1	6.8	70.3	54.7	15.6	64.0	61.0	3.0
9	Orono, Me., -	17.3	18.4	-1.1	21.9	12.3	9.6	15.9	20.3	-4.4
10	Putnam, Ct., -	34.8	40.2	-5.4	47.8	22.9	24.9	37.9	36.1	1.8
	Average, 30-39,	32.5	32.0	0.5	38.2	24.7	13.5	32.6	31.6	1.0
	1888-91.									
11	Brooklyn, Ct., -	27.9	29.8	-1.9	35.0	20.3	14.7	30.4	26.4	4.0
12	Putnam, Ct., -	32.0	34.3	-2.3	38.1	26.2	11.9	35.7	29.4	6.3
13	S. Manchester, Ct.,	29.8	29.9	-0.1	37.6	19.4	18.2	30.6	28.8	1.8
14	Lebanon, Ct., -	16.6	18.0	-1.4	20.9	12.4	8.5	16.4	18.4	-2.0
15	N. Woodstock, Ct.,	10.5	13.7	-3.2	17.7	4.2	13.5	10.7	13.5	-2.8
16	Franklin, Ct., -	25.6	28.9	-3.3	30.2	22.8	7.4	25.9	28.5	-2.6
17	Mansfield, Ct., -	34.7	32.7	2.0	35.3	31.9	3.4	33.8	33.9	-0.1
18	Putnam, Ct., -	27.8	27.4	0.4	32.7	20.8	11.9	28.3	30.0	-1.7
	Average, 40-47,	25.6	26.8	-1.2	30.9	19.8	11.1	26.5	26.1	0.4
	Average, (30-47),	29.4	29.2	0.2	35.0	22.5	12.5	29.9	29.2	0.7
	<i>Potatoes.</i>									
	1878-80.									
19	Calais, Vt., -	135.3	127.5	7.8	133.5	129.2	4.3	127.8	135.0	-7.2
20	Lunenburg, Vt., -	85.0	65.0	20.0	105.0	45.0	60.0	80.0	70.0	10.0
21	Orono, Me., -	71.0	64.3	6.7	81.3	54.0	27.3	93.0	42.3	50.7
22	Putnam, Ct., -	69.8	64.3	5.5	91.3	35.7	55.6	70.5	63.3	7.2
23	Mansfield, Vt., -	94.5	92.8	1.7	142.5	44.8	97.7	102.5	84.7	17.8
24	Lunenburg, Vt., -	257.5	225.0	32.5	281.3	201.2	80.1	301.3	181.5	120.0
25	Cabot, Vt., -	142.5	151.0	-8.5	192.3	101.3	91.0	150.0	143.5	6.5
26	Putnam, Ct., -	120.0	110.0	10.0	124.5	104.0	20.5	119.0	111.3	7.7
27	Falls Village, Ct.,	179.8	195.5	-15.7	200.3	175.0	25.3	197.0	178.3	18.7
	Average, -	128.4	121.7	6.7	150.2	98.9	51.3	137.9	112.2	25.7

TABLE 26.

Effects of Individual Ingredients of Fertilizers on Corn and Potato Crops, with Sandy to Loam Soil.

Reference No.	LOCALITY.	NITROGEN.			PHOSPHORIC ACID.			POTASH.		
		Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).
	<i>Corn.</i>									
	1878-1881.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
28	Irasburgh, Vt., -	21.8	17.3	4.5	20.6	18.4	2.2	26.1	12.9	13.2
29	West Rupert, Vt., -	51.3	44.1	7.2	48.4	47.1	-1.3	50.7	44.8	5.9
30	Plainfield, Vt., -	39.3	37.5	1.8	41.1	35.7	5.4	35.1	41.7	-6.6
31	Brattleboro, Vt., -	31.6	31.7	-0.1	36.3	32.1	4.1	37.2	31.1	6.1
32	Watertown, Ct., -	43.0	25.9	17.1	45.6	23.2	22.4	47.0	21.8	25.2
33	Taunton, Mass., -	15.7	12.0	3.7	19.3	10.7	8.6	17.2	12.8	4.4
34	Bridgewater, Mass., -	28.0	19.4	8.6	32.3	15.1	17.2	21.1	26.4	-5.3
35	Plymouth, Mass., -	29.7	16.2	13.5	25.2	20.7	4.5	27.5	18.4	9.1
36	Pomfret, Vt., -	31.2	30.8	0.4	33.4	28.7	4.7	30.6	31.5	-0.9
37	Taunton, Mass., -	49.6	54.4	-4.8	57.8	43.6	14.2	53.7	48.9	4.8
38	S. Pomfret, Vt., -	39.7	34.3	5.4	35.5	36.1	-0.6	43.8	30.2	13.6
39	Middletown, Ct., -	52.3	50.3	2.0	48.5	55.4	-6.9	56.0	45.4	10.6
40	Pittsford, Vt., -	59.2	45.2	14.0	49.1	49.6	-0.5	49.5	49.1	0.4
41	Taunton, Mass., -	30.9	22.4	8.5	29.9	23.4	6.5	30.9	22.4	8.5
42	Cheshire, Ct., -	50.9	51.1	-0.2	51.9	50.1	1.8	49.8	52.3	-2.5
43	Middletown, Ct., -	43.1	40.9	2.2	49.8	32.0	17.8	40.3	44.6	-4.3
44	Middleboro, Mass., -	41.3	41.2	0.1	47.4	35.0	12.4	39.5	42.9	-3.4
	Average, -	38.7	33.8	4.9	39.5	32.9	6.6	38.6	34.0	4.6
	1888-1891.									
	CONNECTICUT.									
45	New Britain, -	34.8	24.8	10.0	27.7	31.0	-3.3	31.6	29.1	2.5
46	Brooklyn, -	38.9	32.7	6.2	34.7	38.2	-3.5	34.8	38.1	-3.3
47	Falls Village, -	37.1	31.6	5.5	33.5	36.3	-2.8	41.6	25.6	16.0
48	Lime Rock, -	21.6	15.1	6.5	16.7	20.3	-3.6	20.9	14.7	6.2
49	Oxford, -	24.6	24.0	0.6	25.6	22.7	2.9	31.2	15.1	16.1
50	New Britain, -	11.0	7.4	3.6	10.2	8.5	1.7	9.5	9.4	0.1
51	Danielsonville, -	19.5	19.0	0.5	25.1	11.6	13.5	23.5	13.6	9.9
52	Falls Village, -	22.8	16.3	6.5	19.1	21.2	-2.1	29.2	7.7	21.5
53	Oxford, -	24.9	20.3	4.6	24.4	20.9	3.5	30.5	12.8	17.7
54	E. Woodstock, -	54.8	43.3	11.5	49.1	50.8	-1.7	50.4	49.2	1.2
55	Wapping, -	41.6	37.7	3.9	39.5	40.5	-1.0	45.6	32.4	13.2
56	Canterbury, -	37.6	21.3	16.3	29.7	31.7	-2.0	32.3	28.3	4.0
	Average, 45-56,	30.8	24.5	6.3	27.9	27.8	0.1	31.8	23.0	8.8
	Average, 28-56,	35.4	29.9	5.5	34.7	30.7	4.0	35.8	29.5	6.3

TABLE 26.—(Continued.)

Reference No.	LOCALITY.	NITROGEN.			PHOSPHORIC ACID.			POTASH.		
		Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).	Plots With.	Plots Without.	Gain or Loss (-).
	MASSACHUSETTS.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
57	Freetown, -	29.7	25.2	4.5	30.7	24.2	6.5	27.1	27.9	-0.8
58	Marblehead, -	28.8	23.1	5.7	26.0	26.0	0.0	27.4	24.0	3.9
59	Shelburne, -	43.7	38.2	5.5	43.0	38.8	4.2	44.7	37.2	7.5
60	Worcester, -	58.6	53.5	5.1	57.9	54.2	3.7	57.6	54.5	3.1
61	Amherst, -	47.6	43.7	3.9	48.4	42.8	5.6	57.9	33.4	24.5
62	Marblehead, -	35.7	28.1	7.0	31.6	32.1	-0.5	36.1	27.7	8.4
63	Bridgewater, -	15.3	12.5	2.8	15.5	12.3	3.2	19.4	8.3	11.1
64	Freetown, -	27.7	21.1	6.6	26.5	22.3	4.2	27.0	21.8	5.2
65	Yarmouth, -	27.5	23.7	3.8	22.8	28.3	-5.5	27.6	23.6	4.0
66	Worcester, -	42.8	41.1	1.7	43.7	40.2	3.5	46.0	38.0	8.0
67	Westfield, -	18.5	12.5	6.0	22.0	8.9	13.1	16.5	14.4	2.1
68	Shelburne, -	26.6	24.2	2.4	28.7	22.2	6.5	26.4	24.5	1.9
69	Amherst, -	58.8	61.2	-2.4	63.0	57.0	6.0	67.5	52.5	15.0
70	Sunderland, -	41.8	39.1	2.7	44.3	36.6	7.7	49.4	31.5	17.9
71	Wilbraham, -	50.4	39.7	10.7	47.9	42.3	5.6	54.4	35.7	18.7
	Average, -	36.9	32.5	4.4	36.8	32.5	4.3	39.0	30.3	8.7
	RHODE ISLAND.									
72	Kingston, -	38.8	41.0	-2.2	40.5	38.7	1.8	44.6	33.2	11.4
73	Hope Valley, -	32.2	32.6	-0.4	33.0	23.6	9.4	33.5	30.8	2.7
74	Noose Neck, -	33.0	29.3	3.7	26.5	34.0	-7.5	29.7	33.8	-4.1
75	Lime Rock, -	50.4	65.9	15.3	56.7	57.4	-0.7	57.4	56.4	1.0
76	Abbott Run, -	33.3	33.6	-0.3	35.5	30.7	4.8	32.4	34.8	-2.4
77	Summit, -	26.3	25.4	0.9	31.8	18.1	13.7	27.0	24.5	2.5
78	Dansville, -	63.5	60.8	2.7	62.9	61.6	1.3	65.1	58.8	6.3
79	Myatt Point, -	48.7	42.4	6.3	43.1	41.8	1.3	43.6	41.2	2.4
80	Kingston, -	20.2	21.0	-0.8	25.2	14.3	10.9	23.4	16.7	6.7
81	Westerly, -	34.5	28.4	6.1	37.5	24.3	13.2	34.0	29.1	4.9
82	Summit, -	25.2	23.9	1.3	38.4	6.2	32.2	25.3	23.7	1.6
83	Abbott Run, -	25.5	21.3	4.2	28.4	18.1	10.3	23.3	24.2	-0.9
84	Hope Valley, -	36.0	22.4	13.6	34.8	24.0	10.8	34.3	24.8	9.5
85	Jamestown, -	39.4	28.5	10.9	34.1	35.5	-1.4	36.2	32.7	3.5
86	Noose Neck, -	28.8	24.3	4.5	28.2	28.5	-0.3	29.2	23.8	5.4
	Average, -	35.7	33.4	2.3	37.1	30.5	6.6	35.9	32.6	3.3
	Potatoes.									
	1878-1880.									
87	Peacham, Vt., -	156.3	154.3	2.0	163.0	145.3	17.7	165.5	142.0	23.5
88	Bridgewater, Mass., -	80.0	69.0	11.0	94.5	54.5	40.0	73.5	75.5	-2.0
89	Lee, Mass., -	68.5	68.0	0.5	73.0	63.5	9.5	81.0	55.5	25.5
90	West Rupert, Vt., -	117.3	113.8	3.5	107.3	123.8	-16.5	131.3	99.8	31.5
91	Taunton, Mass., -	72.4	59.4	13.0	93.2	38.7	54.5	79.6	52.3	27.3
	Average, -	98.9	92.9	6.0	106.2	85.2	21.0	106.2	85.0	21.2

CO-OPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The Station has continued its co-operative field experiments with fertilizers through a fifth year, the general plan being similar to that of former years. The experiments for 1892 have been "Soil Tests," with the exception of one "Special Nitrogen" experiment on oats.

The details of the work were under the care of Mr. Bailey up to July 1st, the time of his resignation as Assistant Agriculturist; since then the writer has had supervision of the work.

The following persons have co-operated in the experiments during the past year:

	POST OFFICE.					
R. S. HINMAN, - - - - -	-	-	-	-	-	Stevenson.
WILLIAM CRANE, - - - - -	-	-	-	-	-	Broad Brook.
W. W. GREEN, - - - - -	-	-	-	-	-	Wapping.
M. H. & H. G. SPERRY, - - - - -	-	-	-	-	-	Bolton.
E. A. HOXIE, - - - - -	-	-	-	-	-	Lebanon.
C. H. LATHROP, - - - - -	-	-	-	-	-	North Franklin.
A. B. WEBB, - - - - -	-	-	-	-	-	Brooklyn.
E. T. WHITE, - - - - -	-	-	-	-	-	Pomfret Landing.

In connection with nearly all of the experiments, rainfall records have been kept during the growing season. On page 58 will be found the rainfall records for the six months ending Oct. 31st, for twenty localities in the State.

MOISTURE TESTS OF CORN.

Pounds Required for a Bushel of Dry Shelled Corn.

The percentages of water at harvest in the corn of the different experiments are found to vary considerably. The field weights are not an accurate measure of the feeding value of the crop. The moisture and the proportions of cob to corn vary widely on different fields, but have been found to be fairly uniform on different plots on the same field. Moisture tests of the corn, at the time of harvest, have been made for each experiment in order to find the number of pounds of ears required to make a bushel of dry shelled corn. Samples of the hard ears (good) and of the

soft ears and nubbins (poor), representing about an average of the crop, were taken separately. These were partially dried in a warm room, and after the samples had reached about a constant weight, were re-weighed, shelled, and the proportion of corn and cob obtained. Small samples of the grain were then sealed in jars, and taken at once to the laboratory for complete moisture determinations.

TABLE 27.

Percentages of Dry Matter of Corn in Ears (Grain and Cob), and the Number of Pounds of Ears Required for a Bushel of Shelled Corn.

NAME AND LOCALITY.	Water-free Corn in Sample (Ears) at Harvest.		Pounds of Ears at Harvest to Equal 56 lbs. of Shelled Corn, with 11 % Water.	
	Good.	Poor.	Good.	Poor.
	%	%	Lbs.	Lbs.
R. S. Hinman, Stevenson, - -	61.6	56.1	81	89
William Crane, Broad Brook, - -	62.8	54.7	80	91
M. H. & H. G. Sperry, Bolton, - -	63.7	53.6	79	93
E. A. Hoxie, Lebanon, - - -	55.6	48.2	90	104
C. H. Lathrop, North Franklin, -	58.7	46.8	85	107
A. B. Webb, Brooklyn, - - -	57.4	48.1	87	104
E. T. White, Pomfret Landing, -	61.6	54.6	81	91

From table 27 it will be seen that the percentages of water-free corn on the ears, at the time of harvest, ranged from 55.6 to 63.7 per cent. The differences here shown may be ascribed to two causes, variations in the proportions of cob to corn, and variations in the amounts of moisture contained in the corn. The proportion of cob to corn seems to have the greatest influence over the amount of dry matter of grain in the crop.

The Sperry Brothers grew a variety that "filled out" well, and the proportion of cob was relatively small. Mr. Hoxie's corn was not well filled out, and the relative amount of cob was large. The amount of ears at harvest required to make one bushel of merchantable grain (11 per cent. water), varies from 79 to 90 pounds. From experiments covering three years, it is found that the average weight of corn at harvest required for one bushel of dry shelled corn (11 per cent. water), is 84 pounds. This is from 10 to 15 pounds more than the amount generally estimated by farmers.

From 70 to 75 pounds is commonly considered sufficient to equal a bushel of well dried corn.

SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consisted in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station, in standard commercial forms, such as nitrate of soda, sulphate of ammonia, dried blood, dissolved bone-black, and muriate of potash. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus \$2 per ton for mixing and freights.

On the following pages, the comparative yields are shown by means of diagrams. The fertilizers and the weights are given at the left of the diagram. The length of the line represents the comparative yield per acre of shelled corn from the different plots. The figures given in the last column show the number of bushels of shelled corn per acre. At the close of this article will be found a series of tabular statements giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

EXPERIMENT BY R. S. HINMAN.

Mr. Hinman's field is located near the Housatonic river. The soil is a light loam, with a sandy to gravelly subsoil, and appears to be river terrace formation. The experiment has been continued through five years with the same order of plots and the same kinds and amounts of fertilizers, with the exception of Plot H.

In table 28 are given the yields of dry shelled corn for the five years through which the experiment has been conducted, together with the average. For the first three years potash had a greater effect on the yields than had the other two ingredients. The results for the past two years indicate that the phosphoric acid in the soil has become greatly reduced where none has been added, so this ingredient has become nearly as essential to the production of a crop on these plots as potash. All three ingredients, nitrogen, phosphoric acid, and potash, have been essential to the production of a fair crop in the past two years. Previous to 1891, nitrogen and potash (Plot E) gave nearly as good results as the complete mixture (Plot G).

In 1890 the difference between these two plots (E and G) was on five bushels, while in 1891 it was 13, and in 1892, 10 bushels.

TABLE 28.

Soil Test with Fertilizers on Corn, During Five Years.

BY R. S. HINMAN, OXFORD.

Plot.	FERTILIZERS PER ACRE.				1888.	1889.	1890.	1891.	1892.	Average.
	Kind.	Lbs. per Acre.	Cost per Acre.							
A	Nitrate of Soda, - -	160	\$ 3.96	Lbs.	29.4	12.2	8.9	9.1	12.0	14.3
B	Dissolved Bone-black, -	320	4.40	Lbs.	21.9	17.4	12.7	17.8	10.3	16.0
C	Muriate of Potash, - -	160	3.48	Lbs.	25.1	22.5	19.4	18.8	10.4	19.2
D	{ Nitrate of Soda, - -	160	8.48	Lbs.	32.7	15.8	16.9	28.9	16.0	22.1
	{ Dissolved Bone-black, -	320		Lbs.						
E	{ Nitrate of Soda, - -	160	7.52	Lbs.	3.55	33.3	34.5	27.4	17.3	29.6
	{ Muriate of Potash, - -	160		Lbs.						
O	Nothing, - - -	-	—	Lbs.	27.8	12.5	14.4	19.8	20.7	19.0
F	{ Dissolved Bone-black, -	320	8.00	Lbs.	37.3	32.0	28.7	27.0	22.9	29.6
	{ Muriate of Potash, - -	160		Lbs.						
G	{ Nitrate of Soda, - -	160	12.00	Lbs.	42.8	37.1	39.4	40.3	27.5	37.4
	{ Muriate of Potash, - -	160		Lbs.						
H	Plaster, - - -	400	1.70	Lbs.	30.6	14.1	14.4	—	—	19.7
I	Complete Fertilizers, varied forms, - - -	600	12.93	Lbs.	44.4	31.1	27.2	35.7	14.1	30.5

Comparative Results with Different Fertilizing Ingredients.

NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
25.9	21.1	4.8	26.3	20.7	5.6	29.0	18.0	11.0

The results indicate that an incomplete fertilizer cannot be economically used for several years without gradually reducing the other ingredients from the soil. Although, perhaps, abundant at first, the unsupplied ingredients become exhausted in time and profitable cultivation is no longer possible. The relative importance of nitrogen, phosphoric acid, and potash, is shown by the following tabulation:

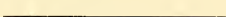
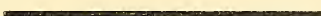
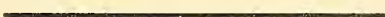
Yields per Acre with and without Different Fertilizing Ingredients.

NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
25.9	21.1	4.8	26.3	20.7	5.6	29.0	18.0	11.0

From this it will be seen that potash had the leading effect, while nitrogen and phosphoric acid caused considerable increase. The results for the five years lead to the conclusion that potash needs to be used in quite large quantities for corn on this soil, while nitrogen and phosphoric acid should be more sparingly supplied. The mixture on plot G has given good yields and a financial gain each year, but would very likely be improved by the addition of 50 pounds more of muriate of potash. The small yields obtained on all the plots in 1892, were probably due to the dry season.

SOIL TEST WITH FERTILIZERS ON CORN 1892.

By R. S. HINMAN, OXFORD.
(P. O., Stevenson.)

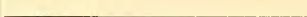
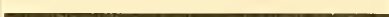
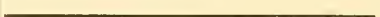
Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - - -	—		12.0
A.	Nitrate of Soda, -	160		10.3
B.	Dis. Bone-black, -	320		10.4
C.	Muriate of Potash, -	160		16.0
D.	{ Nitrate of Soda, - 160 { Dis. Bone-black, - 320	{		17.3
E.	{ Nitrate of Soda, - 160 { Muriate of Potash, 160	{		20.7
F.	{ Dis. Bone-black, - 320 { Muriate of Potash, 160	{		22.9
G.	{ Nitrate of Soda, - 160 { Dis. Bone-black, - 320 { Muriate of Potash, 160	{		27.5
H.	Plaster, - - -	400		16.3
oo.	Nothing, - - -	—		14.1

EXPERIMENT BY WILLIAM CRANE.

The field on which Mr. Crane's experiment was conducted was a "run out" field of nearly level land, that had been alternately cropped and fallowed without the use of manure and with but small quantities of commercial fertilizers. Owing to the size and shape of the field, it was found necessary to extend the last four plots of the experiment (oo, H, G, and F) on to land of a different texture, and which had been differently treated from the rest of the lot. The soil of this portion of the field was lighter in color and appeared to contain less organic matter. It had been planted to beans in 1891, and gave a poor crop. The balance of the field was fallow, and there was upon it a light growth of weeds, which of course added somewhat to the organic matter of the soil and the supply of fertilizers in the crop. For these reasons only the first six plots of the experiment should be considered.

SOIL TEST WITH FERTILIZERS ON CORN.

BY WILLIAM CRANE, ELLINGTON.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		21.2
A.	Nitrate of Soda, -	160		36.3
B.	Dis. Bone-black, -	320		25.7
C.	Muriate of Potash,	160		32.3
D.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }			37.5
E.	{ Nitrate of Soda, - 160 } { Muriate of Potash, 160 }			36.2
F.	{ Dis. Bone-black, - 320 } { Muriate of Potash, 160 }			10.8
G.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 } { Muriate of Potash, 160 }			20.1
H.	Plaster, - -	400		11.4
oo.	Nothing, - -	—		12.7

From the plots having the fertilizing ingredients supplied singly, (A, B, and C), it will be seen that nitrogen had the lead-

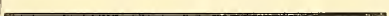
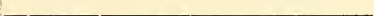
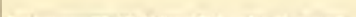
ing effect on the crop, potash standing next, while phosphoric acid gave considerable increase over the nothing plot. The results on this part of the experiment seem to indicate that a complete fertilizer containing relatively small quantities of phosphoric acid with liberal proportions of potash and nitrogen, would prove most economical for corn on this soil.

EXPERIMENT BY M. H. AND H. G. SPERRY.

The field selected by the Sperry Brothers was a light loam soil with a sandy subsoil. The land had a gentle slope to the west (the oo side of the field). Plots H and oo were apparently more moist than the remaining plots, and as the season was somewhat dry, these two plots probably gave relatively larger crops than would otherwise have resulted. Owing to the more favorable condition for a good crop found in the soil of plot oo, the increase or decrease over nothing has been compared with plot o.

SOIL TEST WITH FERTILIZERS ON CORN.

BY M. W. & H. G. SPERRY, BOLTON.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		52.6
A.	Nitrate of Soda, -	160		58.6
B.	Dis. Bone-black, -	320		52.3
C.	Muriate of Potash, -	160		51.5
D.	{ Nitrate of Soda, - 160 }	{ 320 }		57.3
	{ Dis. Bone-black, - 320 }			
E.	{ Nitrate of Soda, - 160 }	{ 320 }		62.8
	{ Muriate of Potash, - 160 }			
F.	{ Dis. Bone-black, - 320 }	{ 160 }		53.8
	{ Muriate of Potash, - 160 }			
G.	{ Nitrate of Soda, - 160 }	{ 320 }		64.3
	{ Muriate of Potash, - 160 }			
H.	{ Dis. Bone-black, - 320 }	{ 400 }		62.7
	{ Plaster, - - - 400 }			
oo.	Nothing, - -	—		59.5

The relative results from the use of nitrogen, phosphoric acid, and potash are shown in the following tabulation:

Yields per Acre with and without Different Fertilizing Ingredients.

NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Loss With.	Plots With.	Plots Without.	Gain With.
60.8	55.1	5.7	56.9	58.9	-2.0	58.1	57.7	0.4

In this experiment nitrogen has had the leading effect. On all of the plots there was considerable increase. This increase was most marked when the nitrogen was combined with potash. The results are in accord with other experiments in this State made on light loam soils. Corn on such soils is generally benefited by potash and nitrogen, while phosphoric acid has a much less effect. The effects of the fertilizers did not appear very marked on any of the plots, probably owing to the fact that a heavy sod was plowed in, which added considerably to the fertility of the soil. The Messrs. Sperry are to continue the experiment through a second year.

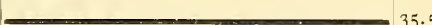
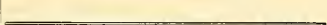
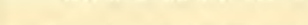
EXPERIMENT BY E. A. HOXIE.

Mr. Hoxie's field was part of an old pasture lot that had not been plowed or manured for twenty years. The soil was a light loam, with a sandy to gravelly subsoil. The soil appeared to be fairly uniform, with the exception that a section across one end of the plots was somewhat gravelly. Plot 00 for some unknown reason seemed to be naturally more fertile than the other plots, and as the results were probably abnormal, it has not been included in the tabulation.

Notwithstanding the apparent uniformity of soil just mentioned, the results indicate that this varied considerably in fertility, a condition which may have been due in part to differences in the moisture holding powers of the soil. The portion of the field including plots E, F, and G, was on higher ground and probably was affected by drouth more than other portions of the field. All three ingredients seem to be lacking in this soil.

SOIL TEST WITH FERTILIZERS ON CORN.

BY EDWARD HOXIE, LEBANON.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		21.3
A.	Nitrate of Soda, -	160		30.5
B.	Dis. Bone-black, -	320		24.8
C.	Muriate of Potash, -	160		30.6
D.	{ Nitrate of Soda, - 160 Dis. Bone-black, - 320 }	{ 160 320 }		35.5
E.	{ Nitrate of Soda, - 160 Muriate of Potash, - 160 }	{ 160 160 }		30.7
F.	{ Dis. Bone-black, - 320 Muriate of Potash, - 160 }	{ 320 160 }		34.9
G.	{ Nitrate of Soda, - 160 Dis. Bone-black, - 320 Muriate of Potash, - 160 }	{ 160 320 160 }		33.1
H.	Plaster, - -	400		28.7

The relative results from different fertilizing ingredients are shown as follows:

Yields per Acre with and without Different Fertilizing Ingredients.

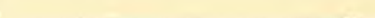
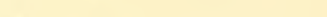
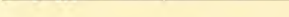
NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
31.5	29.8	1.7	32.1	30.1	2.0	32.4	29.9	2.5

EXPERIMENT BY C. H. LATHROP.

The field selected for Mr. Lathrop's experiment was part of an old meadow that had been mowed and pastured for four years without manure. The land had a gentle slope to the east, and the plots were laid out up and down the slope. The soil is a medium loam, with a yellow, sandy loam subsoil.

SOIL TEST WITH FERTILIZERS ON CORN.

BY C. H. LATHROP, NORTH FRANKLIN.

Plot.	FERTILIZERS.		YIELD SHELLLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		34.7
A.	Nitrate of Soda, -	160		39.4
B.	Dis. Bone-black, -	320		42.8
C.	Muriate of Potash, -	160		43.8
D.	{ Nitrate of Soda, - 160 }	{ 320 }		45.9
	{ Dis. Bone-black, - 320 }			
E.	{ Nitrate of Soda, - 160 }	{ 320 }		44.2
	{ Muriate of Potash, - 160 }			
F.	{ Dis. Bone-black, - 320 }	{ 160 }		40.2
	{ Muriate of Potash, - 160 }			
G.	{ Nitrate of Soda, - 160 }	{ 320 }		41.7
	{ Dis. Bone-black, - 320 }			
H.	{ Muriate of Potash, - 160 }	{ 400 }		35.0
	{ Plaster, - - - 400 }			
oo.	Nothing, - -	—		31.6

All three of the essential ingredients seem to be lacking in the soil, as indicated by the increase occurring where these were used singly and in combinations of twos. The reason for the smaller increase on G than on some of the other plots may be accounted for by the dryer condition of the soil on that side of the field.

The relative results from the use of nitrogen, phosphoric acid, and potash are shown in the following tabulation:

Yields per Acre with and without Different Fertilizing Ingredients.

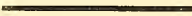
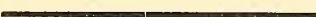
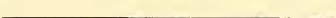
NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
42.8	40.5	2.3	42.7	40.6	2.1	42.5	40.8	1.7

EXPERIMENT BY E. T. WHITE.

Mr. White's field was part of an area of "plain land," evidently a terrace formation of the Quinnebaug river. The soil is a sandy loam and the subsoil fine sand. The field had grown corn for three years prior to 1891, with small applications of stable manure. The crop had been good. In 1891 rye was grown, and the field was again sown to rye for the year 1892. The rye was quite uniform and about three inches high when the land was plowed for the experiment.

SOIL TEST WITH FERTILIZERS ON CORN.

BY E. T. WHITE, POMFRET LANDING.

Plot.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		23.9
A.	Nitrate of Soda, -	160		36.1
B.	Dis. Bone-black, -	320		21.6
C.	Muriate of Potash,	160		18.6
D.	{ Nitrate of Soda, -	160 }		30.6
	{ Dis. Bone-black, -	320 }		
	{ Nitrate of Soda, -	160 }		
E.	{ Muriate of Potash,	160 }		37.2
	{ Dis. Bone-black, -	320 }		
	{ Muriate of Potash,	160 }		
F.	{ Nitrate of Soda, -	160 }		19.8
	{ Dis. Bone-black, -	320 }		
	{ Muriate of Potash,	160 }		
G.	{ Nitrate of Soda, -	160 }		31.3
	{ Dis. Bone-black, -	320 }		
	{ Muriate of Potash,	160 }		
H.	Plaster, - -	400		15.6
oo.	Nothing, - -	—		14.0

The marked increase from the use of nitrogen is quite unusual. Corn as a rule does not respond very markedly to soluble nitrogenous fertilizers. In our experiments on corn the best results with nitrogen in the form of nitrate of soda have been obtained on fine textured, light loam soils.

The tabulation on the next page shows the relative results from the use of the different fertilizing ingredients.

Yields per Acre with and without Different Fertilizing Ingredients.

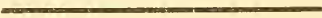
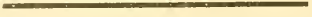
NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Loss With.	Plots With.	Plots Without.	Gain With.
33.8	18.9	14.9	25.8	26.9	-1.1	26.7	26.0	0.7

EXPERIMENT BY A. B. WEBB.

The field selected by Mr. Webb was a worn-out alluvial soil near the Quinnebaug river. The soil is a fine light loam, with a subsoil very similar, except there is an absence of organic matter. On the west side (plots G, H, and oo), the soil is much shallower and appeared to be less fertile. The field had been alternated with fallow and buckwheat for several years without the use of manures.

SOIL TEST WITH FERTILIZERS ON CORN.

BY A. B. WEBB, BROOKLYN.

Plot.	FERTILIZERS.		YIELD SHELLLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		23.1
A.	Nitrate of Soda, -	160		34.1
B.	Dis. Bone-black, -	320		24.9
C.	Muriate of Potash, -	160		23.3
D.	{ Nitrate of Soda, -	160		32.6
	{ Dis. Bone-black, -	320		
E.	{ Nitrate of Soda, -	160		31.8
	{ Muriate of Potash, -	160		
F.	{ Dis. Bone-black, -	320		29.2
	{ Muriate of Potash, -	160		
G.	{ Nitrate of Soda, -	160		39.9
	{ Dis. Bone-black, -	320		
H.	{ Muriate of Potash, -	160		19.8
	{ Plaster, - -	400		
oo.	Nothing, - -	—		8.9

Nitrogen seems to be the essential ingredient, although all three ingredients were needed to produce a fair crop. The unusual increase from nitrate of soda alone (Plot A) was probably due to the more fertile condition of the land. This condition was apparent when the field was visited in August, although it could not be accounted for.

The relative results from the three fertilizing ingredients are shown by the following:

Yields per Acre with and without Different Fertilizing Ingredients.

NITROGEN.			PHOSPHORIC ACID.			POTASH.		
Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.	Plots With.	Plots Without.	Gain With.
34.6	24.3	10.3	31.7	27.3	4.4	31.1	27.9	3.2

EXPERIMENT BY THE STATION ON OATS.

The oat experiment carried out on the Station land was the third crop in a rotation soil test experiment. The field was planted to corn in 1890, potatoes in 1891, and to oats this year, the order of plots and the fertilizers being the same each season.

The land was prepared for seeding April 8th, and April 9th was sown with common western oats at the rate of two and one-half bushels per acre. The fertilizer was applied to all of the plots April 14th. The seed germinated well and there was a fairly uniform stand.

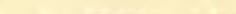
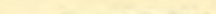
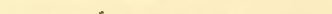
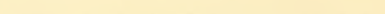
Notes were taken several times during the season, and it was noticed that the crop on the plots to which nitrogen had been applied in the fertilizers was in all cases larger and more advanced than where no nitrogen was used. Phosphoric acid also produced considerable effect wherever used, and especially where used with nitrogen, while potash was the least useful. Phosphoric acid appeared to hasten the maturity of the crop. On all plots where this ingredient was used, the oats were in the best condition for cutting from five to seven days earlier than those on plots receiving no phosphoric acid.

It will be seen from table 37 at end of this article that the weights per bushel of grain did not vary greatly. The heaviest oats were not always found on the plots that yielded most. While

nitrogen increased the yield considerably, it did not seem to increase the weight per bushel, as will be seen by comparing plots A and G with B and F.

SOIL TEST WITH FERTILIZERS ON OATS.

By THE STATION, STORRS.

Plot.	FERTILIZERS.		YIELD PER ACRE. (Grain.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		29.1
A.	Nitrate of Soda, -	160		36.0
B.	Dis. Bone-black, -	320		27.0
C.	Muriate of Potash,	160		26.3
oo.	Nothing, - -	—		24.2
D.	{ Nitrate of Soda, -	160 }		37.9
	{ Dis. Bone-black, -	320 }		
E.	{ Nitrate of Soda, -	160 }		30.0
	{ Muriate of Potash,	160 }		
F.	{ Dis. Bone-black, -	320 }		27.8
	{ Muriate of Potash,	160 }		
G.	{ Nitrate of Soda, -	160 }		39.4
	{ Dis. Bone-black, -	320 }		
	{ Muriate of Potash,	160 }		
ooo	Nothing, - -	—		22.5
X.	{ Stable Manure, -	12,000 }		40.9
	{ Dis. Bone-black, -	160 }		
Y.	Stable Manure, -	16,000		41.3

The yields of both grain and straw were greatest on the plots to which nitrogen and phosphoric acid were applied, while potash seemed to be of little use. Plot D, with 160 pounds of nitrate of soda and 320 pounds of dissolved bone-black, gave only 1.5 bushels less of oats and 200 pounds less of straw than plot G, which had the same fertilizers with the addition of 160 pounds of muriate of potash. The cost on plot D was \$8.48 and on G \$12. The experiment illustrates very well the importance of having fertilizers adapted to the needs of the crop and the peculiarities of the soil. Oats are heavy nitrogen feeders, and are, as a rule,

greatly benefited by nitrogenous fertilizers. If this point is understood, and then the peculiarities of the soil as regards phosphoric acid and potash are taken into account, fertilizers for the crop may be rationally and economically compounded.

For practical deductions and conclusions from this class of experiments the reader is referred to the summary of field experiments on pages 77-80.

SPECIAL NITROGEN EXPERIMENT ON OATS.

The object of this class of experiments is to study the effect of larger and smaller quantities of nitrogen on different crops, while the amount of mineral fertilizers remains constant. There are two prominent points to be considered: the effect of the fertilizer on the yield, and the effect on the composition and feeding value.

Experiments of this kind have been conducted during the past year on grass and oats. The experiment on grass will be found on pages 36-46 of this Report, and that upon oats by Mr. Green follows.

The field where this experiment is located has been in grass for several years without manure, and yielded less than one ton of hay per acre. The soil is in the red sandstone region of the Connecticut valley, and is a light loam with a subsoil of much the same character to the depth of 2 to 2½ feet. Below this is a medium fine, red sand.

The oats were sown April 15, and the fertilizer was applied and rolled in a few days later.

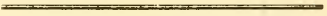
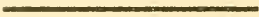
The crop made a fair growth throughout the season, and was not materially injured by blight or drouth. The crop on plots 8 and 9 became lodged quite badly soon after the oats were in blossom. This seems to have checked the development of the grain and reduced the yield beyond what might otherwise have been expected. The weights per bushel were somewhat less on plots 8 and 9 than on plot 7, which would indicate that the crop on these plots failed to mature as fully as on plots where the crop did not lodge.

Plot 6 was on the end of the field nearest the highway, and it seems probable that the land there had not been long under

cultivation. The mixed mineral plots gave but little increase over nothing. The average of four mixed mineral plots was 21.3 bushels. The addition of 160 pounds of nitrate of soda to the minerals increased the yield of grain 9 bushels and of straw 675 pounds, at an increased cost of four dollars for the fertilizers. The nitrate of soda gave a much larger increase than dried blood, while the cost of the two mixtures (plots 7 and 13) are practically the same. The extent to which nitrogen can be profitably used is not clearly shown in this experiment, owing to the lodging on plots 8 and 9.

SPECIAL NITROGEN EXPERIMENT ON OATS.

BY W. W. GREEN, WAPPING.

Plot.	FERTILIZERS.		YIELD PER ACRE. (Grain.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
0.	Nothing, - - - -	—		25.6
6.	{ Dis. Bone-black, { Mixed } { Mur. of Potash, { Minr'ls }	{ 320 } { 160 }		23.8
<i>Nitrate of Soda Group.</i>				
7.	{ Nitrate of Soda, - - -	{ 160 } { 480 }		30.6
8.	{ Nitrate of Soda, - - -	{ 320 } { 480 }		30.0
9.	{ Nitrate of Soda, - - -	{ 480 } { 480 }		35.0
*6a	Mixed Minerals, as 6,	- 480		17.8
*6b	Mixed Minerals, as 6,	- 480		21.6
<i>Dried Blood Group.</i>				
13.	{ Dried Blood, - - -	{ 200 } { 480 }		25.0
14.	{ Dried Blood, - - -	{ 400 } { 480 }		25.6
15.	{ Dried Blood, - - -	{ 600 } { 480 }		26.9
6c.	Mixed Minerals, as 6,	- 480		21.9
000	Nothing, - - - -	—		18.1

* Plots 6a and 6b were separated by three plots which are not here reported upon.

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 29.—By R. S. HINMAN, OXFORD (P. O., STEVENSON).

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, -	—	—	50	51	101	6.2	5.8	1010	—
A.	Nitrate of Soda, -	160	3 96	34	54	91	4.2	6.1	910	-1.7
B.	Dis. Bone-black, -	320	4 40	44	44	101	5.4	5.0	1010	-1.6
C.	Muriate of Potash, -	160	3 48	76	58	117	9.4	6.6	1170	4.0
D.	{ Nitrate of Soda, -	160 }	8 48	79	67	136	9.7	7.6	1360	5.3
	{ Dis. Bone-black, -	320 }								
E.	{ Nitrate of Soda, -	160 }	7 52	113	59	142	14.0	6.7	1420	8.7
	{ Muriate of Potash, -	160 }								
F.	{ Dis. Bone-black, -	320 }	8 00	143	46	232	17.7	5.2	2320	10.9
	{ Muriate of Potash, -	160 }								
G.	{ Nitrate of Soda, -	160 }	12 00	183	43	237	22.6	4.9	2370	15.5
	{ Dis. Bone-black, -	320 }								
	{ Muriate of Potash, -	160 }	12 28	98	37	185	12.1	4.2	1850	4.3
H.	{ Special Mixture,* -	625 }								
I.	{ Complete fertilizer, } Varied forms, }	600	12 93	81	36	205	10.0	4.1	2050	2.1

* Nitrate of Soda, 75 lbs.; High Grade Blood, 100 lbs.; Dis. Bone-black, 200 lbs.; Muriate of Potash, 250 lbs.

TABLE 30.—By WILLIAM CRANE, ELLINGTON.

No. of Plot.	FERTILIZERS PER ACRE.				YIELD PER PLOT 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots.	
				Good.	Poor.		Good.	Poor.			
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.	
O.	Nothing, -	—	—	157	15	95	19.6	1.6	950	—	
A.	Nitrate of Soda, -	160	3 96	280	12	263	35.0	1.3	2630	19.3	
	Dis. Bone-black, -	320	4 40	194	13	234	24.3	1.4	2340	8.7	
C.	Muriate of Potash, -	160	3 48	249	11	297	31.1	1.2	2970	15.3	
D.	{ Nitrate of Soda, -	160 }	8 48	290	11	308	36.3	1.2	3080	20.5	
	{ Dis. Bone-black, -	320 }									
E.	{ Nitrate of Soda, -	160 }	7 52	283	7	307	35.4	0.8	3070	19.2	
	{ Muriate of Potash, -	160 }									
F.	{ Dis. Bone-black, -	320 }	8 00	70	18	179	8.8	2.0	1790	-6.2	
	{ Muriate of Potash, -	160 }									
	{ Nitrate of Soda, -	160 }	12 00	153	9	292	19.1	1.0	2920	3.1	
G.	{ Dis. Bone-black, -	320 }									
	{ Muriate of Potash, -	160 }	1 70	79	14	138	9.9	1.5	1380	-5.6	
H.	{ Plaster, -	400 }									
oo.	Nothing, -	—	—	82	22	137	10.3	2.4	1370	—	

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 33.—By C. H. LATHROP, NORTH FRANKLIN.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water.		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	281	17	190	33.1	1.6	1900	—
A.	Nitrate of Soda, -	160	3 96	327	10	219	38.5	0.9	2190	6.2
B.	Dis. Bone-black, -	320	4 40	350	17	225	41.2	1.6	2250	9.6
C.	Muriate of Potash, -	160	3 48	366	7	257	43.1	0.7	2570	10.6
D.	{ Nitrate of Soda, -	160 }	8 48	379	14	290	44.6	1.3	2900	12.7
	{ Dis. Bone-black, -	320 }								
E.	{ Nitrate of Soda, -	160 }	7 52	362	17	287	42.6	1.6	2870	11.0
	{ Muriate of Potash, -	160 }								
F.	{ Dis. Bone-black, -	320 }	8 00	338	4	274	39.8	0.4	2740	7.0
	{ Muriate of Potash, -	160 }								
G.	{ Nitrate of Soda, -	160 }	12 00	347	10	307	40.8	0.9	3070	8.5
	{ Dis. Bone-black, -	320 }								
	{ Muriate of Potash, -	160 }								
H.	Plaster, - -	400	1 70	292	6	211	34.4	0.6	2110	1.8
oo.	Nothing, - -	—	—	257	15	218	30.2	1.4	2180	—

TABLE 34.—By E. T. WHITE, POMFRET LANDING.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.			Shelled Corn. 11 % Water.		Stover.	Gain or Loss (-) over Nothing Plots
				Good.	Poor.	Stover.	Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O.	Nothing, - -	—	—	185	10	209	22.8	1.1	2090	—
A.	Nitrate of Soda, -	160	3 96	291	2	211	35.9	.2	2110	17.1
B.	Dis. Bone-black, -	320	4 40	169	6	160	20.9	.7	1600	2.6
C.	Muriate of Potash, -	160	3 48	148	3	186	18.3	.3	1860	-.4
D.	{ Nitrate of Soda, -	160 }	8 48	245	4	281	30.2	.4	2810	11.6
	{ Dis. Bone-black, -	320 }								
E.	{ Nitrate of Soda, -	160 }	7 52	296	6	237	36.5	.7	2370	18.2
	{ Muriate of Potash, -	160 }								
F.	{ Dis. Bone-black, -	320 }	8 00	157	4	214	19.4	.4	2140	.8
	{ Muriate of Potash, -	160 }								
G.	{ Nitrate of Soda, -	160 }	12 00	248	6	234	30.6	.7	2340	12.3
	{ Dis. Bone-black, -	320 }								
	{ Muriate of Potash, -	160 }								
H.	Plaster, - -	400	1 70	122	5	173	15.1	.5	1730	-3.4
OO.	Nothing, - -	—	—	110	4	135	13.6	.4	1350	—

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 35.—By A. B. WEBB, BROOKLYN.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn, 11 % Water.		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, - - -	—	—	170	37	324	19.5	3.6	2340	—
A.	Nitrate of Soda, - -	160	3 96	278	22	350	32.0	2.1	3500	18.1
B.	Dis. Bone-black, - -	320	4 40	183	41	275	21.0	3.9	2750	8.9
C.	Muriate of Potash, - -	160	3 48	149	64	295	17.1	6.2	2950	7.3
D.	{ Nitrate of Soda, - -	{ 160	{ 8 48	234	59	273	26.9	5.7	2730	16.6
	{ Dis. Bone-black, - -	{ 320								
E.	{ Nitrate of Soda, - -	{ 160	{ 7 52	219	69	311	25.2	6.6	3110	15.8
	{ Muriate of Potash, - -	{ 160								
F.	{ Dis. Bone-black, - -	{ 320	{ 8 00	211	52	340	24.2	5.0	3400	13.2
	{ Muriate of Potash, - -	{ 160								
G.	{ Nitrate of Soda, - -	{ 160	{ 12 00	310	45	417	35.6	4.3	4170	23.9
	{ Dis. Bone-black, - -	{ 320								
H.	{ Muriate of Potash, - -	{ 160	{ 1 70	114	70	224	13.1	6.7	2240	3.8
	{ Plaster, - - -	{ 400								
oo.	Nothing, - - -	—	—	48	35	118	5.5	3.4	1180	—

SOIL TEST WITH FERTILIZERS ON OATS.

TABLE 36.—By THE STATION, STORRS.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT, 1-12 ACRE.		YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Oats.	Straw.	Oats.	Straw.	Gain over Nothing Plots.	Weight per Bushel.
		Lbs.	\$	Lbs.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
o.	Nothing, - - -	—	—	75	105	29.1	1260	—	30.9
A.	Nitrate of Soda, - -	160	3 96	90	140	36.0	1680	10.7	30.0
B.	Dis. Bone-black, - -	320	4 40	72	117	27.0	1404	1.7	32.0
C.	Muriate of Potash, - -	160	3 48	66	102	26.3	1224	1.0	30.1
oo.	Nothing, - - -	—	—	63	93	24.2	1116	—	31.2
D.	{ Nitrate of Soda, - -	{ 160	{ 8 48	102	167	37.9	1998	12.6	32.2
	{ Dis. Bone-black, - -	{ 320							
E.	{ Nitrate of Soda, - -	{ 160	{ 7 52	80	145	30.0	1740	4.7	32.0
	{ Muriate of Potash, - -	{ 160							
F.	{ Dis. Bone-black, - -	{ 320	{ 8 00	76	120	27.8	1434	2.5	32.6
	{ Muriate of Potash, - -	{ 160							
G.	{ Nitrate of Soda, - -	{ 160	{ 12 00	105	182	39.1	2184	14.1	32.0
	{ Dis. Bone-black, - -	{ 320							
ooo.	{ Muriate of Potash, - -	{ 160	{ 1 70	114	70	22.4	1116	1.0	30.1
	{ Plaster, - - -	{ 400							
oo.	Nothing, - - -	—	—	61	87	22.5	1044	—	32.5
X.	{ Stable Manure, - -	{ 12000	{ 18 80	106	177	40.9	2124	15.6	31.1
	{ Dis. Bone-black, - -	{ 160							
V.	Stable Manure, - -	16000	19 20	114	187	41.3	2244	16.0	33.1

TABLE 37.
SPECIAL NITROGEN EXPERIMENT ON OATS.

By W. W. GREEN, WAPPING.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT 1-10 ACRE.		YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Oats.	Straw.	Oats.	Straw.	Gain or Loss over Nothing Plots.	Weight per Bushel.
		Lbs.	\$	Lbs.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
0	Nothing, - -	—	—	71	155	25.6	1550	—	27.7
6	{ Dis. Bone-black, { Mixd } { Mur. of Potash, { Minls }	320 } 160 }	8 00	62	146	23.8	1460	1.9	26.1
	<i>Nitrate of Soda Group.</i>								
7	{ Nitrate of Soda, - -	160 }	12 00	89	210	30.6	2100	8.7	29.1
	{ Mixed Minerals, as 6, -	480 }							
8	{ Nitrate of Soda, - -	320 }	15 96	85	220	30.0	2200	8.1	28.3
	{ Mixed Minerals, as 6, -	480 }							
9	{ Nitrate of Soda, - -	480 }	19 92	90	345	35.0	3450	13.1	25.7
	{ Mixed Minerals, as 6, -	480 }							
6a*	Mixed Minerals, as 6, -	480	8 00	49	158	17.8	1580	-4.1	27.5
6b*	Mixed Minerals, as 6, -	480	8 00	60	144	21.6	1440	-0.3	27.8
	<i>Dried Blood Group.</i>								
13	{ Dried Blood, - - -	200 }	11 95	73	201	25.0	2010	3.1	29.2
	{ Mixed Minerals, as 6, -	480 }							
14	{ Dried Blood, - - -	400 }	15 90	76	258	25.6	2580	3.7	29.7
	{ Mixed Minerals, as 6, -	480 }							
15	{ Dried Blood, - - -	600 }	19 85	78	265	26.9	2650	5.0	29.0
	{ Mixed Minerals, as 6, -	480 }							
6c	Mixed Minerals, as 6, -	480	8 00	63	122	21.9	1220	0	28.8
000	Nothing, - - -	—	—	52	109	18.1	1090	—	28.7

* Plots 6a and 6b were separated by three plots which are not reported upon.

BACTERIA IN THE DAIRY.*

BY H. W. CONN.

IV. THE ISOLATION OF RENNET FROM BACTERIA CULTURES.

Ever since the beginning of the study of micro-organisms it has been a debated question whether fermentations are to be regarded as purely biological or purely chemical phenomena, or as partaking of both characters. Beginning with the work of Schwann and others in the early part of the century, careful experimentation, aided by microscopic study, seemed to point to a biological explanation of nearly all forms of fermentation which had hitherto been considered as purely chemical. The work of the third and fourth decades of the century proved beyond question that most fermentations were always intimately associated with the growth of micro-organisms, and the inference was a natural one that the micro-organisms themselves were the cause of the fermentations. Shortly after the valuable work of Schwann had started this thought, appeared the brilliant investigations and discussions of Liebig upon fermentations in general. By Liebig all fermentations were regarded as purely chemical phenomena, and the presence of micro-organisms was regarded only as a concomitant incident. By him all albuminous matter was supposed to tend spontaneously toward decomposition, and such decomposition was the basis of fermentation and decay. This, the chemical theory, was for twenty years the favorite. The biological and chemical theories were at that time very rigidly opposed to each other and supposed to be contradictory. The brilliancy of the exposition of the chemical theory by Liebig resulted in its almost universal acceptance for twenty years, and it was not until the genius of Pasteur was directed toward fermentation that a succession of brilliant experiments finally settled the question as to

*During the past five years investigations on the Bacteria of Milk have been conducted in behalf of the Station by H. W. Conn, Professor of Biology in Wesleyan University. Some of the results have been given in the publications of the Station, as follows: *Bacteria in Milk, Cream, and Butter*, Bulletin 4, and Annual Report for 1889, pp. 52-67. *Ripening of Cream*, Annual Report for 1890, pp. 136-157. *A Micrococcus of Bitter Milk*, Report for 1891, pp. 158-162.

the real relation of organisms to various forms of fermentation, and proved that albuminous matter has in itself no tendency toward decomposition. Pasteur, as every one knows, by excluding all sources of error from his experiments, succeeded in practically disproving the old ideas of spontaneous generation, and in demonstrating, also, that at least a majority of forms of fermentations are caused by micro-organisms. From the time when Pasteur turned his attention to the subject the drift of research and thought was reversed; experimenter after experimenter succeeded in confirming the views of Pasteur, until at last the conclusion was demonstrated beyond peradventure that nothing will undergo fermentation of itself and that most of the forms of fermentations occur only through the influence of bacteria or yeasts.

This explanation, however, was soon seen to be only a partial one; for while it was conclusively demonstrated that micro-organisms produced the fermentations, it still remained a question as to *how* they produced these results. There arose consequently, a number of distinct theories as to the method of these fermentations, the chief of which were the following: The theory of Pasteur regarded certain forms of fermentation which he had studied, as purely biological phenomena, and described them as due to growth without oxygen. In general, this theory assumed that the micro-organisms growing in solutions in which they found no free oxygen, seized oxygen from the molecules of the fermentable material and thus caused a degradation of those molecules which resulted in fermentation. Where plenty of free oxygen was present, other types of chemical change occurred producing putrefactions. A second theory, that of Nägeli, attributed the phenomena to a phase of molecular physics, assuming that certain forms of molecular vibration, which were developed during the growth of the micro-organisms, were transferred to the fermentable material, and this molecular vibration caused the degradation of the fermentable molecules. A third theory was the chemical theory. In accordance with this, the fermentations are, in reality, chemical actions, and produced by certain products of bacteria growth. This last theory has been proved to be true in some cases, and requires further explanation.

In the early study of fermentations, a confusion of ideas naturally led to no clear distinction between different types of fermentation. It was in 1854 that Schroeder and Dusch (An.

d. Chem. u. Pharm., 89, 232) first suggested that fermentations might be divided into two somewhat distinct classes, finding that in some cases the fermentative action was checked by reagents like glycerine, which destroyed organic life, while in other cases the fermentation was not checked by these reagents. This was the first suggestion of a distinction between what we now recognize as organized and unorganized ferments. In later years this distinction has been more clearly drawn, and to-day chemists and biologists everywhere recognize a radical difference between these two forms of fermentation. On the one hand, we have such ferments as are produced by the digestive glands, ptyalin, pepsin, trypsin, rennet, etc., which are not organized, do not grow, and seemingly act by purely chemical means. These ferments are called *enzymes*. On the other hand, we have fermentations, such as those produced by the alcoholic ferments and lactic ferments of milk, which are produced by micro-organisms and only occur when these micro-organisms grow and multiply in the fermentable material. But while we recognize these two distinct types of ferments, it must be admitted that as yet neither the chemists nor the biologists really understand the method of action in either case. The unorganized ferments produce chemical action in the fermentable material, but why they do this and what is the source of energy for the action we do not understand. The organized ferments also produce chemical changes in the fermentable materials, doing so only when growing, but how they produce these changes is equally uncertain.

In recent years there has been a tendency in biological research to show that the two forms of fermentations are, at least in some cases, very closely allied. Certain forms of fermentations, produced by micro-organisms, seem to be identical in their chemical nature with those produced by some unorganized ferments. Various facts have raised the question whether it is not possible that the micro-organisms produce unorganized ferments or enzymes as a result of their growth, perhaps as excretions, and that the immediate cause of the fermentation in these cases is the action of the enzymes, and thus is chemical rather than biological.

The first suggestion in this line resulted from the study of germ diseases, and the gradual development of the theory that the immediate causes of these diseases are certain poisons secreted by the growing bacteria, and known in general as *ptomaines*. These ptomaines are certainly produced by the disease germs

growing in the body, and being extremely virulent poisons act in a deleterious manner upon the tissues of the organisms and give rise to the abnormal symptoms. These ptomaines have been studied for some ten years or more. They have been isolated in many cases from bacteria cultures and their direct actions on the animal body determined by experiment. There is no question that it is to these ptomaines that the deleterious action of bacteria is due, at least in many germ diseases.

In the study of fermentations proper evidence has begun to accumulate in recent years that the immediate cause of the action is, in some cases at least, the production of chemical enzymes. Even as long ago as 1876 it had been pointed out by Pasteur and Joubert (Comp. rend., 1876), that the fermentation of urea into ammonium carbonate was probably produced by a chemical enzyme. In the last ten years a number of investigators, Arloing, Baginsky, Beyerinck, Brunton and Macfadyen, Salkowski, Vignal, Wood, Wortmann, and Hueppe have been convinced by experiments that other organic fermentations, such as the liquefaction of gelatine, the diastatic fermentation, the inversion of sugar by bacteria growth, etc., are in a similar way caused immediately by *unorganized* ferments, which the bacteria have produced. Finally, in 1890, Fermi succeeded for the first time in definitely isolating from bacteria cultures a chemical enzyme which possesses powers quite similar to those of trypsin produced from the pancreas, and is doubtless the cause of the liquefaction of gelatine by bacteria. This enzyme from bacteria cultures peptonizes albuminoids, and in all essential respects, so far as made out by Fermi, agrees with trypsin in its characteristics.

One of Pasteur's first subjects for study was the fermentations of milk, and one of his first successful experiments consisted in the demonstration that milk fermentations are wholly due to the growth of micro-organisms. Pasteur quite early succeeded in discovering that the fermentations which take place in milk are not always alike, but while he distinguished between the lactic acid fermentations and the butyric acid fermentations the difficulties of experiment were so great that no clear classification of milk fermentations was then possible. For twenty years after the publication of Pasteur's first work on milk very little advance on this subject was made. In 1882 Duclaux (Ann. d. l'Inst. Nat. Agronomique, No. 8, 1882-83) pointed out that while the normal fermentations in milk produce lactic acid, and thus render the

reaction of milk acid, under certain conditions, milk will curdle but remain neutral or even become weakly alkaline. This was more likely to occur when milk curdled after being boiled. The curdling of milk under these conditions could not, of course, be due to the precipitation of casein by acid, and for the lack of any better explanation Duclaux attributed the action to the formation by the bacteria growing in the milk of a chemical enzyme having the characteristics of rennet. Two years later Hueppe (*Mith. a. d. Kaiserl. Gesundheitsamte*, 2, 1884) in his classical study on milk fermentations obtained the same results, so far as concerned an alkaline curdling of milk under the influence of certain species of bacteria, and stated that he was also inclined to accept the explanation of Duclaux that the bacteria in question produced a rennet-like ferment. Hueppe was able to offer no experimental evidence for this conclusion. Later, Warrington studying the same subject, also found the alkaline curdling common to many species of bacteria, and noticed that the species of bacteria, which curdle milk and render it alkaline, have the further characteristic of dissolving or peptonizing the curd by their subsequent growth. This peptonizing of the curd he thought must be due to a ferment having the characteristics of trypsin, and inasmuch as trypsin does not have the power to precipitate casein, concluded that these bacteria produce two enzymes, one having the characteristics of trypsin and the other those of rennet.

From this time on, the recognition of the production of a rennet by some species of bacteria has been quite general on the part of bacteriologists who have studied milk problems. The scores of species of bacteria, whose action on milk has been studied, have been classified into various physiological groups, and one of the most prominent of these groups is one which is supposed to produce a rennet-like ferment and to curdle milk by its action. In general, it has been found that the species which produce this rennet also produce the peptonizing ferment, and consequently have the power both of liquefying gelatine and of dissolving the curd of milk after the casein is precipitated. The reverse of this has not seemed, however, to be true, for not all of the species which produce the peptonizing ferment appear to produce the rennet ferment. There have been found, by Adametz (*Oester. Monatsh. f. Thierheilk. und Thierzucht*, 1890), and also by the author (*An. Rep. of Storrs School Station*, 1890), a few species of bacteria which seem to have the peptonizing power without the power

of curdling milk. Under their influence milk is slowly peptonized and rendered transparent, but does not enter into a previous solid or gelatinous condition. In one case it was found that a species of bacteria, which at the outset both curdled the milk by the production of a rennet ferment and subsequently peptonized it, after a long continued cultivation lost the curdling power while retaining the peptonizing power, seeming to indicate that the power of producing rennet had disappeared with cultivation at warm temperature. Further, quite a number of species produce both curdling and peptonizing at low temperature (20° C.), while at higher temperatures (37° C.) only the latter occurs.

Up to the present time no one has ever succeeded in demonstrating the presence of this enzyme rennet by isolating it from bacteria cultures. The work of Fermi on the tryptic ferment produced by micro-organisms was confined wholly to the study of the peptonizing enzyme, although his method of experimentation must doubtless have given him a mixture of the two forms of ferment. His experiments, however, were not designed to indicate the presence of the rennet ferment, and he therefore obtained no evidence of its production.

During the last year some experiments in my laboratory have been directed to this problem, and I have finally succeeded in isolating the rennet ferment, although I have not yet obtained it in a pure condition. The species of bacteria which were used as the basis of the experiments were normal milk bacteria obtained from the cream of a neighboring creamery. From the many species obtained from such ripening cream, there were selected a few forms which seemed to have this rennet producing power well developed, and further experiments with these organisms were conducted as shown in the following pages. The species of bacteria used had the following characteristics:

BACILLUS No. 5.

Morphology. A short, oval bacillus with a capsule, and showing bipolar staining. Somewhat variable in size and smaller in agar and potato than in gelatine. No spore formation seen.

Motility. Rapid motion.

Temperature. Will hardly grow in 37° C. Grows best at about 20° C.

Need of Oxygen. Will not grow under mica.

Plate cultures. A small white colony with dark centre. Soon sinks in a pit and rapidly liquefies.

Gelatine tube. Grows rapidly and produces a rather narrow funnel with a

thick tenacious scum on the surface, showing a tendency to become cracked. Later the liquid becomes green, and finally yellow and slimy.

Agar. Agar turned greenish. A thin, rough layer grows along inoculation line which is marvelously sticky, almost like thick glue; so thick indeed, that it can hardly be picked up with the needle.

Potato. Brownish yellow growth, quite abundant. Potato discolored in vicinity of the streak.

Milk. At temperature of the room it becomes curdled in two days. Curd soft and slimy with little whey. Reaction alkaline. At 35° C. curdling occurs in six days. Curd subsequently digests into a lemon yellow liquid with sickish odor. Hardly any digestion at 35° C. After four months' cultivation the power of curdling milk was lost, while digestive power was retained and the liquid formed by the digestion was not yellow.

Bouillon. Produces a thick scum with clear liquid. Scum sinks on being disturbed. Later the liquid becomes slimy and cloudy.

BACILLUS No. 6.

Morphology. A short oval rod, almost a micrococcus.

Motility. Is not motile.

Temperature. Grows well at 35° C., and also at 20° C. The growth is less rapid at 35° C. and the yellow pigment does not form.

Need of Oxygen. Will not grow under mica.

Plate cultures. Produces a small round yellow colony which sinks into a pit. The colony has a dark centre with a tendency to concentric rings and radial fractures.

Gelatine tube. Gelatine slowly liquefies with a scum on the surface.

Agar. A thin, white, abundantly spreading growth.

Potato. An abundant, thick-raised irregular mass producing a yellow pigment.

Milk. At the temperature of the room a soft coagulum is formed with a neutral reaction, which later becomes alkaline. At 35° no coagulum. The milk becomes digested into a cloudy but transparent blueish liquid with an aromatic and not disagreeable odor. Reaction of the liquid is alkaline. At 35° C. the digestion occurs without previous curdling.

Bouillon. A slight growth giving rise to a clear liquid with a slight precipitate. Liquid later becoming cloudy.

BACILLUS No. 8.

Morphology. Short rods which never form into chains. Spores produced in abundance.

Motility. Is motile.

Temperature. Growth about equally good at 20° and 35°.

Need of Oxygen. Grows well under mica.

Gelatine tube. Grows rapidly, producing a slender narrow funnel, which later broadens out as the gelatine becomes completely liquefied. After complete liquefaction, which requires about two weeks, the gelatine begins to turn red and in a few days becomes a blood red color.

Agar. A thin, white, smooth, spreading growth, not very abundant.

Potato. A thin, smooth glistening grayish white mass, slightly tinged with brown.

Milk. Milk becomes curdled into a soft mass with neutral reaction in 24 to 48 hours, at the temperature of 20° C. or at 35° C. Later becomes red.

Bouillon. A cloudy liquid produced with sediment.

This organism somewhat resembles *B. lactis erythrogenes*, but differs from it in its motility and its growth on agar.

BACILLUS No. 9.

Morphology. A slender rod provided with a capsule. More slender when growing in potato than in gelatine. In gelatine there is a tendency toward a bipolar stain, which does not appear in the organism when growing in potato.

Motility. Is very active.

Need of Oxygen. Will not grow under mica.

Gelatine tube. Grows rapidly, liquefies the gelatine; forming at first a very shallow pit, which becomes deepened as the gelatine liquefies.

Agar. Produces a thin, spreading growth, which at first is hardly visible, but later becomes thick and white.

Potato. A thin, grayish, glistening mass, spreading diffusely over potato surface.

Milk. Milk is curdled in the room into a soft mass with neutral reaction. At 35° C. the curdling does not take place. By later growth the curd is digested in the room, and at 35° C. the digestion takes place without the previous curdling.

BACILLUS No. 10.

Morphology. A rod three times as long as broad, showing uniform stain, with no tendency to form chains. In potatoes the rods are more slender and longer than in gelatine. No spore formation observed.

Temperature. Grows well at 35° C. and also at 20° C.

Need of Oxygen. Will not grow under mica.

Gelatine tube. Liquefies, forming a very thin shallow pit, which deepens into a uniform layer in liquid gelatine. After a few days gelatine becomes greenish.

Agar. A thin, transparent, white, spreading growth.

Potato. A thin, grayish layer spreading over potato surface.

Milk. Milk is curdled readily at the temperature of the room and also at 35° C. Coagulum is soft and has a neutral reaction. Later it becomes digested by the further action of the organism, both at 35° C. and at 20° C.

BACILLUS No. 31.

Morphology. Slender short rods showing a bipolar stain. When growing in bouillon, the bipolar stain is not seen. No spore formation observed.

Need of Oxygen. Will not grow under mica.

Colony. A small, rounded, granular colony, which sinks into a liquefied pit.

Gelatine. A shallow funnel, which rapidly liquefies.

Agar. A rather thin, whitish growth along the needle track, which later becomes quite thick. Does not spread very widely.

Potato. A thick, solid growth of a salmon yellow color; later becoming deep salmon and very thick.

Milk. Milk becomes alkaline and transparent. No curdling takes place, but the digestion of the peptone seems to go on in a normal manner. Sometimes at the temperature of the room a curdling occurs previous to digestion.

Bouillon. A flocculent, cloudy mass, collecting at the top and bottom of the liquid, with a clear space between.

BACILLUS No. 32.—(*Bacillus fluorescens liquefaciens.*)

Morphology. A small, short rod, sometimes forming chains in bouillon. Slightly longer in bouillon than in gelatine or on potato.

Need of Oxygen. Aerobic.

Temperature. Grows either at 20° C. or at 35° C., but growth is less abundant at 35° C.

Plate culture. A small, rapidly liquefying pit, surrounded by green fluorescence.

Agar. A thick white, smooth growth on the surface, turning the agar greenish.

Potato. A thick, moist layer, with a tinge of salmon color.

Milk. At the temperature of the room a very slight, slimy curd is produced in one or two days, which is followed rapidly by a complete digestion, turning the milk into a semi-transparent mass with the characteristic green color. At 35° C. the curdling did not make its appearance, although the milk became digested in the usual manner.

Bouillon. An abundant growth, tingeing the whole bouillon with olive green.

With these organisms, experiments have been carried on as follows:

EXPERIMENT I.

The first problem that presented itself was to determine whether a soluble ferment was formed by the bacteria cultures. For this purpose one of the organisms, No. 5, was inoculated into an Erlenmeyer's flask containing sterilized milk. In this the bacteria were allowed to grow for nine days at the normal temperature of the room (about 20°). At the end of that time the milk had become curdled by the action of the rennet, and the curd was partially dissolved. A small amount of water was then added to the culture in order to make the amount of liquid a little greater and to assist in the solution of the enzymes and render filtration easier, and then the whole was filtrated through a porcelain cylinder. There was obtained a clear, slightly colored filtrate. A small amount of this filtrate was put into a test tube containing sterilized milk and the tube placed in a culture oven at a temperature of 37° C. The milk in the

tube became curdled in less than two hours. A gelatine culture was then made from the curdled milk in order to determine whether by any accident the filters had not worked successfully and the bacteria had found their way into the filtrate. The gelatine culture showed no growth, and thus it was demonstrated that the curdling in this case must have been due to some soluble ferment in the filtrate. Parallel with this experiment, a second was conducted in a similar way, except that the organism was cultivated in beef peptone bouillon instead of milk. The filtrate from this culture obtained from the porcelain cylinder did not, in the first experiment, show any power to curdle milk.

EXPERIMENT 2.

Having thus shown the presence of a soluble enzyme in the filtrate, the next problem was to isolate it from its solution. For this purpose the same organism was again cultivated in sterilized milk, filtered at the end of two weeks through a porcelain cylinder, and the filtrate treated with a large amount of strong alcohol. There appeared an abundant precipitate. The precipitate was then allowed to stand under the alcohol for two weeks in a closely stoppered bottle. At the end of that time the precipitate had settled to the bottom of the alcohol and the alcohol was easily decanted from it, leaving the clear precipitate at the bottom. This precipitate was then dissolved in sterilized water. The precipitate dissolved completely. A small amount of this solution was then added to a test tube of sterilized milk and placed at 37° C. The milk was curdled in one and one-half hours. The curdled milk was allowed to stand at 37° C. for two days, to see if the curd became digested. No digestion of the curd made its appearance. The rest of the water solution was again treated with alcohol, which once more precipitated the enzyme. The alcohol was then filtrated off and the precipitate collected and dried. It was thus obtained in the form of a grayish, hard mass, which was found to still retain the power of curdling milk when dissolved in water. This material was kept for several weeks in the laboratory and tested at intervals with like results. The curdling of the milk under the influence of the material was rather slow, requiring several hours' action, and from this the conclusion was reached that the rennet existed in this precipitate only in small quantities and by no means in a pure state.

Having thus obtained a rennet enzyme from one organism, similar experiments were made with the other species in the above list. No. 10 was treated in the same way, but proved to be a slower growing organism and required a longer time for successful experiment. After a cultivation of six weeks, however, it was found possible to obtain rennet from the culture, but in rather small quantity. In the same way the species, Nos. 6, 8, 9, 12, 31, and 32, were experimented with, cultures being made in all cases in milk, and in all cases it was possible to obtain by the method above described a certain amount of rennet ferment from the culture after the organism had grown in it for a proper length of time.

The experiments upon these organisms, however, showed considerable variation in the amount of the precipitate which was obtained by the use of alcohol, and more particularly in the readiness with which this precipitate would coagulate milk. After several experiments it was found that Nos. 8 and 9 produced rennet in the greatest quantity and most rapidly, and these two species were therefore used primarily in all of the following experiments. It was plain from the various sets of experiments that the precipitate obtained from alcohol was by no means pure rennet, but contained in addition the tryptic ferment studied by Fermi, and not unlikely other impurities. Fermi isolated his enzyme by alcohol in a method similar to that described above. The next problem that arose, therefore, was to separate the two ferments from each other, if possible. This, however, has proved to be an extremely difficult and thus far impossible task. Both are soluble in the same materials and both ferments obey essentially the same chemical laws. After some experiments I finally adopted the method of separation of rennet originally employed by Blumenthal, which consisted in the precipitation of the rennet by an excess of common salt. In the isolation of rennet from the gastric secretions, this method has proved to be successful in separating rennet from all traces of pepsin, and my first experiments with the method seemed to indicate that it was also capable of separating the two ferments present in my solutions. Later experiments, as will be shown below, have indicated that the separation of the two ferments by this method is by no means complete, but still the method does partially separate them.

From a large number of experiments upon the organisms I selected a few for description.

EXPERIMENT 3.

Organism 9 was inoculated into flasks of sterilized milk and allowed to grow for fourteen days. By this time the digestion of the casein had been largely affected, and after adding a little water to the culture, the whole was filtered through a porcelain cylinder. The filtrate by experiment was found to be active in its curdling power. The filtrate was then acidified very slightly with an extremely weak solution of H_2SO_4 , and then there was added to the solution common salt in large quantities, until there was an excess of salt. When the solution had reached about its limit of dissolving the salt there began to appear a brownish precipitate, which collected on the surface of the liquid instead of sinking to the bottom. This precipitate was removed with a spatula and with a filter and then dissolved in a small quantity of water. The solution was once more acidified with H_2SO_4 , and again treated with salt to saturation. The precipitate made its reappearance floating on the surface, this time, however, almost pure snow-white, the reprecipitation and solution having served to purify the precipitate. The snow-white mass was now collected on a filter and dried, becoming then a fine snow-white powder. A portion of this powder was dissolved in a small amount of water, the solution added to sterilized milk in a test tube, placed at $35^\circ C.$, and curdling of the milk occurred in one hour. In order to determine whether the ferment thus obtained contained the tryptic ferment in any considerable quantity, a little of the water solution was added to a test tube of solidified gelatine in order to determine if a peptonization of the gelatine took place. No appreciable solution of the gelatine occurred; from which the conclusion was drawn that the precipitate did not contain the tryptic ferment in any considerable quantity.

EXPERIMENT 4.

Organism No. 8 was inoculated into a flask of sterilized milk, and allowed to grow for four weeks. After adding to the culture a little water, it was filtered through porcelain and the rennet was isolated as in the previous experiment, by common salt. After the separation of the snow-white precipitate, which appeared when the salt was added, the filtrate was allowed to drop into strong alcohol. This produced a second precipitate, composed partly of salt and partly of a white flocculent mass. The latter was separated so far as possible from the salt precipitate, and was collected

on a filter and dried. In this way a second white powder was obtained, which was supposed to contain the tryptic ferment. Upon adding a little of the solution of this last ferment to milk, a second portion to a little fibrin, it was found that no appreciable digestion either of the casein or of the fibrin took place. The sterilized milk was found after a long time to become curdled, but coagulation took place very slowly. This water solution, however, did possess the power of peptonizing gelatine, since it readily liquefies solidified gelatine in a few hours. This indicates that it contains a certain quantity of tryptic ferment, and consequently shows that the use of salt to precipitate the rennet and then alcohol to precipitate the tryptic ferment is a means of at least partially separating the two ferments.

It is a little surprising to find that, although the organisms when growing in milk do have the power of digesting milk casein, the tryptic ferment obtained as above described, does not possess this power. My only explanation at present is that the porcelain cylinder holds back much of the ferment mechanically, and the filtrate contains only a fraction of the amount originally present. It has been recently pointed out by Duclaux (*Ann. de l'Inst. Pasteur*, 1892, p. 854) that such an effect is produced by porcelain filters. If the porcelain filter has this effect, it would apply equally well to the rennet ferment. Indeed some experiments seem to point to the conclusion. For example, organism No. 6, as shown, usually gave rennet in its solution, but in some experiments no traces of rennet would be found in the porcelain filtrate, although the culture had been carried on as usual. Seemingly the porcelain cylinder had in this case held back all of the rennet ferment.

Similar experiments with organisms Nos. 5, 10, 31, and 32, gave like results. In the case of organisms Nos. 31 and 32, however, the separation of the two ferments proved to be less satisfactory than in the other cases. The salt precipitation seemed to possess a strong power of peptonizing gelatine, and the alcohol precipitate possessed a strong power of curdling milk. This shows that the method adopted for separation of these two ferments is not satisfactory and does not produce a complete separation. At the same time the method of obtaining the rennet from the solution by means of the salt is far more satisfactory than the method of precipitating it by alcohol, and does, at least in some cases, give a

much purer form of the enzyme than is obtained by the simple action of alcohol.

Organisms 6, 9, and 32 were especially interesting for one peculiar feature. These organisms, as will be seen from the description given above, do not possess the property of curdling milk at a high temperature, although doing so at the temperature of the room. All three of them, however, do peptonize the casein, converting it into a somewhat transparent solution of peptonized casein. This occurred in the case of all the organisms when they grow at a temperature of 35° C., as well as at 20° C. The seeming conclusion to be drawn from this is that the organisms in question do not produce the rennet ferment at a temperature of 35° C., but that all of them do produce the tryptic ferment in considerable quantities. It will be seen, however, from the above experiments that this is not a legitimate conclusion, for all three of these organisms are found by experiment to produce rennet in considerable quantity.

EXPERIMENT 5.

For instance, organism 6 is cultivated in the oven at a temperature of 35° C. The milk does not become curdled by the action of the organism, but after two weeks is converted into a partially transparent mass, which plainly indicates a peptonization of the casein. The culture is now filtered through porcelain and the filtrate treated in the manner above described, and there appears as usual the snow-white scum on the surface when the solution has become saturated with salt. This scum, upon being collected, dried, and tested in sterilized milk, is found to contain the rennet ferment, inasmuch as it curdled the milk in a short time. The same result is obtained from experiments with the other two organisms, and we therefore conclude from this that these organisms do produce the rennet ferment under a temperature of 35° C., just as surely as any other of the organisms experimented upon. From experiment 7, described below, it will be seen that the bacillus of hog cholera, which does not curdle milk at any temperature, does produce rennet when growing in milk, thus agreeing with the other organisms studied. We are forced, however, to conclude that the temperature of 35° C. is more favorable for the production of the tryptic ferment, and that this ferment was produced so rapidly at this temperature that it peptonized the casein of the milk before the rennet had accumulated

in sufficient quantity to precipitate it in the form of a solid curd. The same organisms growing at a lower temperature do not produce the tryptic ferment so rapidly, and the rennet ferment is produced in sufficient quantities to precipitate the casein before it is peptonized. In order to test this conclusion the following experiments were made:

EXPERIMENT 6.

Organism No. 8 was inoculated into two flasks of sterilized milk. One was placed at 35°C ., the other was left in the room at a temperature of about 20°C . After growing four days, equal quantities of each solution were filtered through the porcelain cylinder and treated in the normal way for the precipitation of the rennet. It was found that the culture which had been growing at a temperature of 20°C . gave a considerably larger quantity of rennet than the one growing at 35°C . The rennet obtained from the first culture was also much lighter colored than that obtained from the culture which had been at 35°C . This indicated plainly that the latter culture contained a large quantity of products of tryptic digestion. After separating the rennet from the two cultures, the filtrate was treated with a quantity of alcohol to precipitate the other ferments in solution. The precipitate obtained from 35°C . was larger in amount than that obtained from 20°C . This experiment serving as a test of the conclusion above reached, indicated that the temperature of 35°C . is more favorable for the production of a tryptic ferment, while a temperature of 20°C . is more favorable for the production of the rennet ferment.

The impossibility of obtaining any quantitative tests of the amount of rennet produced by the cultures owing to the impurities present, has rendered any further experimentation in this line impossible. It can only be stated in general that in all of the experiments which were carried on, it was found that, provided the organism would grow at all at a temperature of 20°C . the amount of rennet ferment produced at this temperature was considerably greater than the amount produced at a warmer temperature of 35°C ., and all the experiments upon the isolation of rennet were therefore conducted at the lower rather than the higher temperature.

From these experiments it will be seen that the production of rennet does not always make itself evident by a curdling of the milk. Occasionally organisms are found which peptonize milk

without curdling it, and one species has been found by the author that at first possessed both the curdling and peptonizing power, but which lost the former after several months' cultivation. The inference from the above results is that rennet is produced in these cases as in others, but that the peptonizing ferment action disguises it. Indeed, one of the organisms from which I have succeeded in isolating rennet was of this class, refusing to curdle milk at all. Unfortunately, the organism was lost before its characteristics were carefully made out, and it does not therefore appear in the above list. One further set of experiments bearing upon this point is to be mentioned here.

Through the kindness of Dr. Moore, of the U. S. Bureau of Animal Industry, I obtained a culture of the hog cholera bacillus. This organism has no power of curdling milk, but under its influence, both at 35° C. and also at a lower temperature, milk is slowly rendered transparent in the same way as described in the experiment above mentioned. This rendering of the milk transparent was attributed by Dr. Moore to the production of an alkaline reaction and not to any peptonizing ferment. Similar effects can be produced by adding NaOH to milk. The similarity of the action to that in the organisms which have been described above led me to believe that here also there was a production of both a rennet and a tryptic ferment, and the following experiment was made to test the question.

EXPERIMENT 7.

Two flasks of sterilized milk were inoculated with the hog cholera bacillus, one placed at 35° C. and the other at the temperature of the room. The culture placed in the oven failed to curdle, but in two weeks became well digested, or at least it became quite transparent. The culture left in the room was affected the same way only to a less extent. After 18 days one-half of the culture which had been at 35° C. was filtered and treated in the usual manner for the isolation of the rennet ferment. Scarcely any enzyme could be obtained by the use of salt. The very small amount of precipitate which was obtained, however, contained rennet, as was proved by the fact that it curdled milk in about 12 hours. The filtrate from the salt solution was treated with a large amount of strong alcohol to isolate the rest of the enzyme that might be present, and only a very small amount of precipitate was thrown down by the alcohol. The small amount

which was obtained was collected and dissolved in water, but further experiment did not show any power of curdling milk nor of peptonizing gelatine. One week later the culture which had been growing at the temperature of the room, having by this time shown considerable tendency to become transparent, was treated in the same way with precisely similar results, only an extremely small amount of either the rennet or the tryptic ferment being obtained. At the same date, after a growth of 25 days, the other half of the first culture was filtered and the precipitate that appeared upon the addition of salt was a little greater than that of the week before, but was still very small in quantity, and showed only very slight power of curdling milk. The whole precipitate from the culture required 10 hours to produce the curdling of 100 c.c. of milk. The filtrate from the salt solution was treated with alcohol, and, as before, an extremely small amount of precipitate was thrown down by the alcohol. This precipitate, presumably containing the tryptic ferment, was collected on a filter, dissolved in water, and its properties tested. It was found to possess the peptonizing ferment in a very slight degree, and was also found to have a very slight power of curdling milk. The experiment as above described shows that the hog cholera bacillus does produce both rennet and a tryptic ferment, but that the amount of these two ferments produced is extremely small. At least the amount which passes through the porcelain filter is very small. So small is the amount that it is improbable that the digestion of the curd which appears as a result of the action of this organism can be due to the tryptic-like ferment.

The production of rennet ferment by the bacteria in question has been proved to be a rather slow process. The following experiments will indicate that this is true.

EXPERIMENT 8.

Organism No. 10 was inoculated into two flasks of sterilized milk, one placed in the oven and the other kept at the temperature of the room. After five days one-half of each culture was filtered through porcelain, and the rennet isolated from it in the usual way. A very small quantity of rennet was separated by use of the saturated salt solution. Neither the culture growing in the oven nor that in the room had as yet produced rennet in any considerable quantity. Moreover, the small amount of white scum which was separated from the solution by the addition of salt was

found to contain a very small proportion of rennet, inasmuch as it required more than 16 hours to curdle milk by its action. The other half of the same cultures were allowed to grow for six weeks, and at the end of that time again filtered and treated in the usual manner. The amount of rennet produced in this case was much greater than that produced in the earlier test.

EXPERIMENT 9.

Organism No. 8 was in like manner inoculated into flasks of sterilized milk, and after four days' growth one-half of the culture was filtered and treated as usual. An extremely small amount of rennet ferment was produced, such a small amount, indeed, that milk did not curdle in 24 hours by its action. The culture was allowed to grow for five weeks and again treated in the same manner, and a large quantity of rennet was obtained, very strong in its curdling power, precipitating the casein in sterilized milk in one and one-half hours.

In the same way the other organisms studied were found to produce rennet ferment quite slowly, and it was soon found necessary in the experiments to carry on the cultivation of the organisms for something like two weeks in order to be sure of obtaining a sufficient quantity of rennet in the solution to isolate it satisfactorily. This is perhaps a little surprising, inasmuch as the curdling of milk under the influence of the bacteria growth is quite a rapid process and usually occurs inside of a couple of days. It furnishes another indication that much of the enzyme is retained by the porcelain filter.

The rennet that has been isolated from the organisms is certainly not pure. It requires from an hour to eight or ten hours, and sometimes longer, for a considerable quantity of its solution to produce the precipitation of the casein from 100 c.c. of milk, and pure rennet, isolated from the stomach of mammals, acts in a very much shorter time than this. The chemical reactions of the rennet obtained in my experiments do not agree in all respects with the chemical reactions of pure rennet as described by Hamnersten. The difficulty of obtaining this rennet in any considerable quantity has made it impossible, however, at present, to experiment with the enzyme sufficiently to obtain it in any purer condition than that described in the above experiment.

In all of the experiments above described, the rennet was produced by culture of the organism in milk. It is not necessary,

however, to use milk for a culture, since the various organisms will produce these ferments when grown in simple bouillon solutions, although not so readily or in such quantity as when grown in milk. The following three experiments show this fact.

EXPERIMENT 10.

Organism No. 5 was inoculated into a solution of beef peptone bouillon and allowed to grow for two weeks. It was then filtered and treated in the usual manner for the isolation of the rennet. A small quantity of rennet was obtained in this way, which, when dried and dissolved in water, was found to possess the power of precipitating the casein 100 c.c. of milk in a little more than an hour.

EXPERIMENT 11.

Organism No. 10 was inoculated into a solution of beef peptone bouillon plus three per cent. milk sugar. It was allowed to grow in the room for over two months. At the end of that time it was filtered and treated as usual for the separation of rennet. A small quantity of rennet only was obtained from the solution, and the rennet that was obtained was found to possess the curdling power in rather less degree than was possessed by the rennet isolated from the same organism when grown in milk.

EXPERIMENT 12.

Organism No. 8 was in like manner cultivated in bouillon for one week. It was found that a smaller quantity of rennet could be obtained from the solution than was obtained from the culture of the same organism when grown in milk for one day. The rennet isolated had very feeble curdling power, requiring nearly 24 hours to precipitate the casein of milk.

It would seem from these experiments that at least in regard to these three organisms, the production of rennet takes place more readily when the organisms grow in milk than when they grow in bouillon solution.

The following experiments were performed to determine the temperature at which the rennet was destroyed by heat. The difficulty of getting a large quantity of rennet has made it impossible to conduct these experiments as yet in as thorough a manner as desirable, but the two experiments described indicate at all events that the relation of this rennet to high temperatures is essentially the same as that of other enzymes.

EXPERIMENT 13.

A quantity of rennet was isolated from a milk culture of No. 8, and was then dissolved in water and an equal quantity of it added to four tubes containing about 5c.c. of sterilized milk. No. 1 was heated to a temperature of 70° C., No. 2 to a temperature of 74° C., No. 3 to a temperature of 75° C., and No. 4 served as a control experiment. All the test tubes were then placed in an oven at a temperature of 35° C. The control was found to curdle in two hours. None of the other tubes were curdled in 24 hours, but all of them became curdled in 48 hours. Whether this was due to the action of the rennet or to growth of accidental organisms was not determined by the experiment.

EXPERIMENT 14.

Organism No. 10 was cultivated in milk and the rennet isolated in the usual manner. The rennet was dissolved in water and an equal quantity of it added to each of 6 test tubes of sterilized milk. No. 1 served as the control, No. 2 was heated to 60° C. for 5 minutes, No. 3 to 65° C. for 5 minutes, No. 4 to 70° C. for 5 minutes, No. 5 to 75° C. for 5 minutes, and No. 6 to 80° C. for 5 minutes. All were then placed at a temperature of 35° C. No. 1, the control, was found to curdle in five and one-half hours; No. 2 (60°) curdled in 10 hours; No. 3 (65°) in 26 hours; No. 4 (70°) in 44 hours; No. 5 and No. 6 did not curdle at all.

From these experiments it is plain that the bacteria rennet, like other enzymes, is destroyed by a temperature between 70° C. and 80° C., but the exact temperature is somewhat variable, and indeed it would seem that the heat acts gradually in destroying the rennet.

SUMMARY.

(1) *Many species of bacteria that have the power of liquefying gelatine, produce, as a result of their growth in milk, a certain quantity of an enzyme which, so far as can be at present determined, has all of the essential characteristics of rennet.*

(2) *This rennet can be isolated from bacteria cultures by filtering the cultures through a porcelain cylinder and then treating the filtrate with alcohol. A better method, which gives the rennet in a purer condition, though by no means pure, is to precipitate it from its solution by an excess of salt instead of alcohol.*

(3) *It has been found possible to isolate this rennet from milk in the case of all species of bacteria thus far studied which curdle the milk without rendering it acid.*

(4) *Different species of bacteria differ very much in the amount of rennet which they produce and the rapidity with which they produce it.*

(5) *Several species of bacteria have been found to produce rennet in considerable quantity, even where they are not capable of curdling the milk. The explanation of the fact is that the production of a tryptic ferment obscures the production of the rennet ferment in these cases, and the casein becomes peptonized before it can be precipitated by the more slowly forming rennet.*

(6) *The organisms experimented upon seemed in every case to produce a larger amount of rennet when growing at a moderately low temperature than when growing at a temperature of 35° C.*

(7) *The rennet, isolated in this way, has all of the general reactions of dairy rennet, and is subject to destruction by high temperatures in a similar manner.*

FEEDING EXPERIMENTS WITH MILCH COWS ON SOILING CROPS.

BY C. S. PHELPS.

During the summers of 1891 and 1892 the Station has carried on a series of feeding tests with various fodder crops, the soiling system having been followed. The animals were fed in the stables, but had "the run" of a small yard several hours each day. The green fodders were hauled, as a rule, every second day, and a two days' supply weighed at once and left in baskets or separate piles till needed. During all of the tests there was fed a standard grain ration, mixed, in most cases, with cut hay or oat straw. The object of the experiments was to study the value of various green fodders for milk and butter production, and the effect of the rations on the composition of the milk, with especial reference to the quantity of fat produced. In 1891 the fats only were determined, and in 1892 both the fats and solids. The determinations were made at each milking, night and morning. The total amount of butter fat was estimated by multiplying the weight of milk from each milking by its percentage of fat and adding the results for the four or seven days which made up the test.

THE EXPERIMENTS.

During the seasons of 1891 and 1892 green fodder crops were fed from about June 1st till November 1st, and the feeding tests were carried on in 1891 from June 8th till September 22d, and in 1892 from May 29th till August 15th. The amount of green fodder fed varied from 50 to 75 pounds, according to the moisture in the crop. The quantities were regulated more or less by the appetites of the animals. The grain ration remained constant for both seasons and was fed with a small quantity of cut hay or oat straw.

Four animals were used each season, and in 1891 consisted of the following: Cows No. 2 and 5 were grade Jerseys about

seven years old, and had calved during the first week of November, 1890. Their weights at the beginning of the tests were 770 and 830 pounds respectively. Cow No. 1 was a high grade Jersey, six or seven years old, that had calved February 11th, 1891, and weighed 740 pounds, and cow No. 3, a Guernsey and high grade Jersey cross, that had calved February 5th, 1891, and weighed 950 pounds. The same animals were used in the experiments of 1892, with the exception that the grade Jersey No. 5, was replaced by another. No. 5 calved about October 1st, 1891, and weighed June 18th, 1892, 850 pounds. Cow No. 2 calved December, 1891, cow No. 3, February 12th, and cow No. 1, April 3d, 1892. It will be observed that two of the cows were well along in their periods of lactation, having given milk from six to eight months when the tests began, while the other two were two to four months past calving.

The tests in 1891 were each four days in length and in 1892 seven days, and whenever practicable two or more tests were made from the same fodder. In all cases three or four days were allowed to accustom the animals to a new feed before the tests were begun.

COMPOSITION OF THE FODDERS.

Analyses of Green Fodders Grown by Station.

Year.	KIND OF CROP.	Water.	Protein.	Fat.	Nit.-Free Ext.	Fiber.	Ash.	Potential Energy.
		%	%	%	%	%	%	Calor's per lb.
1891	Wheat, - - - - -	69.9	3.7	1.0	14.8	9.0	1.6	550
1892	Wheat, - - - - -	76.2	2.6	.9	12.5	6.3	1.5	440
1892	Wheat, - - - - -	74.2	2.2	1.0	12.9	8.1	1.6	475
1891	Oats and peas, - - -	82.9	3.0	.6	7.4	4.7	1.4	305
1892	Oats and peas, - - -	83.8	3.5	.7	6.2	4.3	1.5	290
1892	Oats and peas, - - -	84.6	3.5	.8	6.0	3.7	1.4	280
1891	Oats and vetch, - - -	75.4	3.6	.7	11.8	6.5	2.0	440
1891	Red clover rowen, - -	70.2	6.0	1.4	13.6	6.7	2.1	550
1891	Timothy and clover rowen,	81.3	3.7	.9	8.0	4.3	1.8	335
1892	Red clover rowen, - -	75.4	4.7	.8	11.1	6.0	2.0	440
1892	Scarlet clover, - - -	79.5	3.1	.8	8.5	6.3	1.8	365
1891	Hungarian, - - - - -	72.8	2.5	.8	14.1	7.7	2.1	485
1891	Hungarian, - - - - -	72.7	3.3	.8	12.6	7.9	2.7	475
1892	Hungarian, - - - - -	71.5	3.1	.9	13.3	9.1	2.1	515
1892	Hungarian, - - - - -	72.4	1.9	.9	14.0	8.6	2.2	500
1891	Cow peas, - - - - -	83.6	3.2	.4	7.7	3.3	1.8	280
1892	Cow peas, - - - - -	88.3	2.5	.4	4.1	3.2	1.5	200
1891	Barley and peas, - - -	84.1	3.0	.6	6.1	4.3	1.9	275

The table which precedes gives the composition of the green fodders used. Each fodder was sampled during the time of feeding, and the results of the analyses are given, calculated to water content at the time of sampling.

THE RATIONS FED.

During most of the trials 60 pounds of green fodder was used per cow per day. The grain remained constant, and consisted of three pounds of corn meal and one pound of new process linseed meal per day, and the dry hay or oat straw varied in amount from three pounds down to nothing, being lessened whenever the animals were inclined to refuse it. Owing to the small number of digestion experiments on green fodders from which data might be had, it was thought best to assume uniform digestion coefficients for all of the fodders. These are essentially the same as Armsby* gives for red clover beginning to blossom, and were as follows: For protein, 75 per cent.; digestible fat, 60 per cent.; nitrogen-free extract, 75 per cent.; and fiber, 50 per cent. The estimates of energy are made as explained in the Report of this Station for 1890, pages 174-181.

From the table (38) of rations, given on the following page, it will be seen that the amount of total digestible nutrients in the fodders varied widely. It will also be noticed that the proportions of protein were largest wherever clover, vetch, peas or other plants of this class entered largely into the rations. By comparison with the standard ration given at the bottom of the table, it will be seen that rations VII., IX., and XIV., which gave the most striking results in the feeding tests, were much narrower, that is, contained a much larger proportion of protein, than that called for by the German standard of Wolff. Recent German experiments on milch cows have shown that better results are obtained from the use of considerably larger quantities of protein than the German standards have hitherto called for.

The difficulties with these experiments as accurate tests are numerous, but are too apparent to require detailed discussion. The small number of cows used, the shortness of the feeding periods, and the variations in the quantities of nutritive materials in the different rations, all interfere with the reliability of the inferences to be drawn, and the results are simply presented for what they are worth.

* Manual of Cattle-feeding.

TABLE 38.—*Amounts of Digestible Nutrients and Calories of Potential Energy in the Rations.*

No. of Ration.	KINDS OF FEED.	Weight as Fed.	Total Dry Matter.	DIGESTIBLE NUTRIENTS.				
				Protein.	Fat.	Carbo- hydrates.	Potential Energy.	Nutritive Ratio.
1891.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	
I.	{ Wheat fodder, - - -	42	12.64	1.16	.26	6.53		
	{ Hay, - - - - -	5	4.29	.21	.07	2.07		
	{ Corn meal, - - -	3	2.60	.22	.10	1.96		
	{ New Process linseed meal, - - -	1	.90	.20	.03	.37		
	Total, - - - - -		20.43	1.88	.46	10.93	25770	1:5.9
II.	{ Timothy and clover, - - -	50	14.45	1.31	.29	7.50		
	{ Grass and hay same as I., - - -		7.79	.72	.20	4.40		
	Total, - - - - -		22.24	2.03	.49	11.90	27980	1:6.5
III.	{ Oats and peas, - - -	50	8.53	1.11	.19	3.94		
	{ Grain same as I., hay 3 lbs. - - -		6.07	.63	.17	3.57		
	Total, - - - - -		14.60	1.74	.36	7.51	18720	1:4.8
IV.	{ Oats and peas, - - -	60	10.23	1.33	.23	4.73		
	{ Grain & hay same as III., - - -		6.07	.63	.17	3.57		
	Total, - - - - -		16.30	1.96	.40	8.30	20770	1:4.7
V.	{ Oats and vetch, - - -	60	14.75	1.63	.26	6.71		
	{ Grain & hay same as III., - - -		6.07	.63	.17	3.57		
	Total, - - - - -		20.82	2.26	.43	10.28	25140	1:5.0
VI.	{ Hungarian, - - - -	60	16.33	1.15	.28	8.68		
	{ Grain & hay same as III., - - -		6.07	.63	.17	3.57		
	Total, - - - - -		22.40	1.78	.45	12.25	27990	1:7.5
VII.	{ Clover rowen, - - -	60	17.89	2.69	.51	8.13		
	{ Hay, - - - - -	2	1.71	.08	.03	.83		
	{ Grain same as I., - - -		3.50	.51	.13	2.33		
	Total, - - - - -		23.10	3.28	.67	11.29	29930	1:4.0
VIII.	{ Hungarian, - - - -	60	16.36	1.49	.28	8.05		
	{ Grain & hay same as VII., - - -		5.21	.59	.16	3.16		
	Total, - - - - -		21.57	2.08	.44	11.21	26530	1:5.9
	{ Clover and timothy rowen, - - -	60	11.20	1.68	.31	4.91		
IX.	{ Grain & hay same as VII., - - -		5.21	.59	.16	3.16		
	Total, - - - - -		16.41	2.27	.47	8.07	21220	1:4.1
X.	{ Cow peas, - - - -	60	10.69	1.25	.17	5.05		
	{ Grain & hay same as VII., - - -		5.21	.59	.16	3.16		
	Total, - - - - -		15.90	1.84	.33	8.21	20090	1:4.9
	{ Wheat fodder, - - -	60	14.87	1.08	.34	7.59		
XI.	{ Oat straw, - - - -	2	1.81	.03	.01	.81		
	{ Corn meal, - - - -	3	2.51	.22	.08	1.89		
	{ New Process linseed meal, - - -	1	.88	.30	.03	.34		
	Total, - - - - -		20.07	1.63	.46	10.63	24750	1:7.2
XII.	{ Oats and peas, - - -	70	11.06	1.85	.32	4.60		
	{ Grain & straw same as XI., - - -		5.20	.55	.12	3.04		
	Total, - - - - -		16.26	2.40	.44	7.64	20530	1:3.6
XIII.	{ Hungarian, - - - -	70	19.95	1.62	.38	10.15		
	{ Grain same as XI., - - -		3.39	.52	.11	2.23		
	Total, - - - - -		23.34	2.14	.49	12.38	29080	1:6.4
XIV.	{ Clover (mixed), - - -	60	12.90	1.57	.27	6.00		
	{ Grain same as XI., - - -		3.39	.52	.11	2.23		
	Total, - - - - -		16.29	2.09	.38	8.23	20600	1:4.4
XV.	{ Hungarian, - - - -	70	19.37	1.00	.37	10.38		
	{ Grain same as XI., - - -		3.39	.52	.11	2.23		
	Total, - - - - -		22.76	1.52	.48	12.61	28310	1:9.1
	German standard for 800 } lb. cow, - - - - - }		19.20	2.00	.32	10.00	23670	1:5.4

THE RESULTS OF THE EXPERIMENTS.

Table 39, which follows, gives the pounds of milk, the pounds of fat, and the average percentages of fat for the four cows, in periods of four days for 1891, and seven days for 1892. The total solids produced in seven days and the average percentage of solids are also given in the results for 1892. It must be borne in mind that as cows advance in their periods of lactation there is a natural shrinkage in the milk flow, and a slow, but more or less gradual rise in the percentage of fat and solids contained in the milk. For this reason only tests that are quite near each other in point of time are comparable.

TABLE 39.
Average Results of Experiments with Four Cows.

No. of Period.	No. of Ration.	KINDS OF FEED.	Milk.	Fat.		Solids.		Butter by Churning.	Milk required to make 1 lb. Butter.
		<i>Periods of 4 days each, 1891.</i>	Lbs.	Lbs.	%	Lbs.	%	Lbs.*	Lbs.
1	I.	Wheat, - - -	327	16.1	5.0	—	—	14.4	23
2	II.	Timothy and clover, -	284	14.4	5.1	—	—	14.0	20
3	II.	Timothy and clover, -	267	13.6	5.1	—	—	13.7	19
4	III.	Oats and peas, -	269	13.3	4.9	—	—	13.9	19
5	IV.	Oats and peas, -	270	13.4	5.0	—	—	14.2	19
6	IV.	Oats and peas, -	266	12.9	4.9	—	—	13.3	20
7	V.	Oats and vetch, -	248	11.9	4.8	—	—	12.5	20
8	V.	Oats and vetch, -	237	11.7	4.9	—	—	12.5	19
9	VI.	Hungarian, -	249	12.4	5.0	—	—	13.1	19
10	VII.	Clover rowen, -	283	15.6	5.5	—	—	16.4	17
11	VII.	Clover rowen, -	289	14.9	5.2	—	—	16.1	18
12	VII.	Clover rowen, -	269	13.7	5.1	—	—	14.4	19
13	VIII.	Hungarian, -	249	12.6	5.1	—	—	12.7	20
14	IX.	Clover and timothy, -	230	13.4	5.8	—	—	13.3	17
15	IX.	Clover and timothy, -	236	12.7	5.4	—	—	13.1	18
16	X.	Cow peas, -	205	11.0	5.4	—	—	10.9	19
17	X.	Cow peas, -	214	11.4	5.3	—	—	11.0	19
18	X.	Cow peas, -	212	11.3	5.3	—	—	11.8	18
		<i>Periods of 7 days each, 1892.</i>							
19	XI.	Wheat, - - -	553	24.7	4.5	74.3	13.5	26.4	21
20	XI.	Wheat, - - -	490	22.6	4.7	68.6	14.1	24.8	20
21	XII.	Oats and peas, -	391	18.4	4.8	54.0	14.0	18.1	22
22	XII.	Oats and peas, -	379	17.5	4.7	51.0	13.6	18.6	21
23	XII.	Oats and peas, -	371	17.2	4.8	49.6	13.8	19.8	19
24	XIII.	Hungarian, -	368	18.1	4.9	50.3	13.8	19.8	19
25	XIV.	Clover, - - -	363	18.5	5.2	51.2	14.1	20.5	18
26	XV.	Hungarian, -	342	16.5	4.9	47.7	13.9	18.9	18

TABLE 40.

Total Pounds of Milk, Butter, Fat, and Average Percentage of Fat, in Periods of 4 Days (1891), and 7 Days (1892).

No. of Period.	No. of Ration.	End of Period.	KINDS OF FEED.	Cow No. 1.			Cow No. 3.			Cow No. 2.			Cow No. 5.		
				Milk.	Fat.	%	Milk.	Fat.	%	Milk.	Fat.	%	Milk.	Fat.	%
		1891.	<i>Periods of 4 days each, 1891.</i>	Lbs.	Lbs.	%	Lbs.	Lbs.	%	Lbs.	Lbs.	%	Lbs.	Lbs.	%
1	I.	June 13.	Wheat, -	94.4	4.2	4.45	97.1	5.0	5.15	64.8	3.7	5.71	70.4	3.2	4.55
2	II.	June 19.	Grass, -	80.2	3.9	4.86	83.5	4.3	5.15	55.6	3.2	5.76	64.5	3.0	4.65
3	II.	June 24.	Grass, -	75.4	3.8	5.04	78.7	3.9	4.96	52.6	3.0	5.70	60.1	2.9	4.83
4	III.	July 2.	Oats and Peas, -	76.8	3.7	4.82	80.0	3.9	4.88	52.2	2.9	5.56	60.3	2.8	4.64
5	IV.	July 10.	Oats and Peas, -	76.8	3.7	4.82	78.2	3.9	4.99	54.9	3.1	5.65	60.1	2.7	4.44
6	IV.	July 17.	Oats and Peas, -	79.3	3.7	4.67	76.5	3.5	4.58	52.4	3.0	5.73	57.4	2.7	4.70
7	V.	July 24.	Oats and Vetch, -	71.3	3.2	4.49	75.4	3.4	4.51	48.0	2.8	5.83	53.6	2.5	4.66
8	V.	July 28.	Oats and Vetch, -	65.0	3.1	4.77	73.4	3.4	4.63	45.7	2.7	5.91	52.9	2.5	4.73
9	VI.	Aug. 3.	Hungarian, -	70.5	3.3	4.68	73.6	3.6	4.89	49.8	2.9	5.82	55.1	2.6	4.77
10	VII.	Aug. 10.	Clover rowen, -	79.8	4.2	5.26	84.6	4.5	5.32	54.2	3.6	6.64	64.1	3.3	5.15
11	VII.	Aug. 14.	Clover rowen, -	77.4	3.8	4.91	89.5	4.4	4.92	55.5	3.4	6.13	66.8	3.3	4.94
12	VII.	Aug. 18.	Clover rowen, -	72.2	3.7	5.12	82.8	3.9	4.71	52.8	3.1	5.87	61.4	3.0	4.89
13	VIII.	Sept. 27.	Hungarian, -	64.9	3.2	4.93	79.1	3.6	4.55	49.7	3.0	6.04	55.3	2.8	5.06
14	IX.	Sept. 2.	Clover and Timothy, -	62.6	3.5	5.59	76.7	4.2	5.48	44.1	2.9	6.58	46.6	2.8	6.01
15	IX.	Sept. 6.	Clover and Timothy, -	65.3	3.4	5.21	81.2	4.1	5.05	43.7	2.7	6.18	45.8	2.5	5.44
16	X.	Sept. 14.	Cow Peas, -	59.4	3.0	5.05	67.0	3.4	5.08	37.4	2.4	6.42	40.7	2.2	5.23
17	X.	Sept. 18.	Cow Peas, -	62.0	3.1	5.00	70.7	3.6	5.09	39.1	2.5	6.39	41.7	2.2	5.23
18	X.	Sept. 22.	Cow Peas, -	59.6	3.0	5.03	73.0	3.6	4.93	37.9	2.4	6.33	41.7	2.3	5.55
<i>Periods of 7 days each, 1892.</i>															
19	XI.	June 5.	Wheat, -	170.9	6.7	3.86	155.1	7.2	4.66	125.4	6.5	5.18	101.2	4.5	4.28
20	XI.	June 12.	Wheat, -	142.8	5.8	4.04	144.7	6.6	4.55	111.6	6.0	5.41	90.6	4.2	4.58
21	XII.	July 3.	Oats and Peas, -	124.5	5.3	4.24	119.3	5.4	4.53	96.6	5.3	5.45	50.3	2.5	4.91
22	XII.	July 10.	Oats and Peas, -	126.1	5.2	4.15	118.5	5.3	4.47	91.0	5.0	5.45	43.6	2.0	4.66
23	XII.	July 17.	Oats and Peas, -	121.0	5.5	4.54	122.4	5.5	4.45	89.7	4.5	5.54	38.3	1.8	4.67
24	XIII.	July 27.	Hungarian, -	117.2	5.4	4.61	123.7	5.8	4.72	84.2	5.1	5.67	36.9	1.7	4.66
25	XIV.	Aug. 7.	Clover, -	118.2	5.7	4.79	129.7	6.1	4.72	82.8	5.1	6.08	30.8	1.6	5.19
26	XV.	Aug. 15.	Hungarian, -	116.9	5.3	4.52	120.4	5.4	4.48	81.2	4.7	5.78	23.5	1.2	4.88

In table 40, on the preceding page, the results are given somewhat in detail for each of the four cows for four-day tests in 1891, and for seven-day tests in 1892.

The tests of especial interest are those with clover and with Hungarian grass Nos. 9-15. In the tests with clover in 1891 it will be noticed that there was, in the case of each cow, considerable increase in the milk flow, in the total fat, and in the percentage of fat in the milk over that of the Hungarian test just preceding. This increase was most marked during the first clover test.

The Hungarian tests following the three clover tests showed, in the case of each cow, a falling off in the total fat, and in the case of cows 1 and 3, a slight decrease in the percentage of fat. During the tests with clover and timothy rowen (Nos. 14 and 15), there was an increase in the percentage of fat varying from fifty-five hundredths to a little less than one per cent. This increase in the percentage of fat was followed, in the case of cows 1 and 3, by a gradual falling off during the succeeding cow pea test. Cows 2 and 5 gave a decided increase in the percentage of fat during these clover tests, but showed only a slight decrease in the percentage during the succeeding cow pea test. This circumstance may perhaps be accounted for by the fact that cows 2 and 5 were then well advanced in their periods of lactation. At such a time the percentage of fat becomes naturally high and seems to remain high without very much regard to feed.

During the experiments of 1892 similar tests were made with clover rowen and with Hungarian. From the tables of composition and the rations fed it will be seen that the clover feed in 1892 was not as rich in protein as in 1891. With all but one of the cows there was an increase in the percentage of fat when clover was fed, over that obtained during the Hungarian test just before, and with each cow a marked falling off in milk flow and percentage of fat when the cows were again given Hungarian. It is of interest to note, in connection with the more marked falling off during the second Hungarian test, that the fodder was much poorer in protein, and hence the ration was much wider than the one used just before the clover test.

SUMMARY.

The best results on quantity and quality of the products were obtained where rations with relatively large amounts of protein were fed. The experiments seem to indicate that rations containing a larger proportion of digestible protein than that called for by the commonly accepted standards are to be preferred. Large, nitrogenous rations are especially important early in the period of lactation, when the productive capacity of the cow is most heavily taxed. The quantity and quality of the products may be improved by the use of foods rich in protein, and the manure is more valuable than where starchy foods are fed.

In these experiments, when clover was fed the amounts of milk and butter were considerably increased, and the percentages of fat were higher than during the Hungarian tests just before and after those with clover. The average product from four cows during the first series of clover tests (Aug. 10, 14, and 18,) of 1891, was 281 pounds of milk and 15.6 pounds of butter, and the average percentage of fat was 5.3 per cent.; while for the Hungarian tests (Aug. 3 and 27,) the average quantity of milk was 249 pounds, and of butter 12.9 pounds, and the average percentage of fat 5.0 per cent.

A STUDY OF ACTUAL DIETARIES.

BY CHARLES D. WOODS.

In the last report of this Station* there was given an account of two dietaries which had been studied by the Station. One was the dietary of a boarding house, the other that of a chemist's family. Since then the Station has made a study of six other dietaries, which are reported herewith in detail. The investigation was made in connection with the United States Department of Labor. The first three reported upon were carried out by Mr. H. M. Smith, at that time Assistant Chemist to the Station; the last three by Dr. H. B. Gibson.

The six dietaries studied were as follows:

1. Dietary of a jeweler's family.
2. Dietary of a blacksmith's family.
3. Dietary of a machinist's family.
4. Dietary of a mason's family.
5. Dietary of a carpenter's family.
6. Dietary of a carpenter's family.

The general plan of the investigation included an account of all food materials of nutritive value in the house at the beginning, that purchased during, and that which remained at the end of the experiment. In addition, all the kitchen and table wastes were collected, weighed and analyzed. The amounts of different food materials on hand at the beginning and received during the experiment were added; from this sum the amounts remaining at the end were subtracted. This gave the amount of each material actually used. From the amount thus obtained and the composition of each material, as shown by analysis, the amounts of the nutritive ingredients were estimated. From these were subtracted the amounts of nutrients in the waste, and thus the amounts of nutrients actually eaten were learned.

*Report of this Station, 1891, pp. 90-106.

An account of the meals taken by the different members of the family, and by visitors, was kept. In this way occasional absences from home or the presence of visitors did not materially affect the experiment. The number of meals for one man, to which the actual meals taken were equivalent, was found, as in the earlier work by Prof. Atwater*. The equivalents are somewhat arbitrary, but are based upon the best data to be obtained. They are as follows :

Estimated Relative Quantities of Potential Energy in Nutriment Required by Persons of Different Classes.

Man at moderate work, -	-	-	-	-	-	-	-	10
Woman at moderate work, -	-	-	-	-	-	-	-	8
Child, 15 to 6 years old, -	-	-	-	-	-	-	-	7
Child, 6 to 2 years old, -	-	-	-	-	-	-	-	5
Child, under 2 years old, -	-	-	-	-	-	-	-	2½

EXPLANATION OF TABLES.

The statistics of the family are concisely given just before the first table of each dietary.

The first table of each dietary (tables 41, 44, 47, 50, 53, and 56) shows the actual amount of food and of nutrients in the food used during the dietary. The weights of the food materials are as they were purchased and used; that is, they include bone and other refuse, except where specified.

The first three columns in the table contain the percentages of protein fat and carbohydrates used in computing the amounts of those nutrients in the different food materials. In all cases where the composition was not fairly well known from previous analyses, specimens of the food materials actually used in the dietary, or specimens as nearly identical as possible, were analyzed. The cases in which special analyses were made in connection with these dietaries are indicated in the table by placing the letter *a* after the name of the material.

The weight of the water-free table and kitchen wastes, and their composition, are given in the last line of the table. Exactly what is included in these wastes is explained in the foot note on page 97 of the Report of this Station for 1891.

The second table of each dietary (tables 42, 45, 48, 51, 54, and 57) gives the summary of the food materials and nutrients used in the dietary, the quantities estimated per man per day, and the

*See especially 17th Annual Report of the Massachusetts Bureau of Statistics of Labor, pp. 239-329.

percentages of food materials of different classes, and of nutrients furnished by each class. The quantities per man per day were found by dividing the weights of the different food materials and nutrients used in the dietary by the number of days for one man, to which the total meals taken were equivalent.

The third (last) table in each dietary (tables 43, 46, 49, 52, 55, and 58) gives the nutrients and potential energy in food purchased, in table and kitchen wastes, and in portion actually eaten. The estimates of animal and vegetable nutrients in the waste are computed as below described, and those of potential energy (fuel-value of nutritive ingredients) as explained in an earlier Report.*

It was not practicable in the collection of the wastes to distinguish between that which came from animal and that from vegetable food. It is, however, possible to estimate with more or less of accuracy how much of the nutritive materials came from the animal and how much from the vegetable foods. As there were practically no carbohydrates in any of the animal foods except milk and cheese, and but little in these, we shall not greatly err in assuming that all the waste carbohydrates came from the vegetable foods. It will also be fairly accurate to assume that the proportions of protein and fat in the vegetable portion of the waste were the same as in the whole vegetable food. Taking the percentages of the weights of the carbohydrates in the total waste as the measure of the protein and fats in the vegetable wastes the actual weights of protein and fat in the latter are readily calculated. Subtracting these weights of vegetable protein and fat from the total weight of these ingredients in the waste, the remainders give the amounts of animal protein and fats in the whole waste.

Table 59 summarizes the results of the eight dietary studies which have been made by the Station.

*Report of this Station, 1890, p. 174.

DIETARY OF A JEWELER'S FAMILY.

The study began Sept. 1, 1891, and continued 30 days.

The family was as follows:—

Man, 70 years old, at very light work.

Man (chemist), 23 years old, moderate exercise.

Woman, 60 years old (assumed = .8 of one man).

Woman, 25 years old, 11 days (assumed as .8 of one man).

The meals taken were equivalent to 285 meals, or 95 days for one man.

TABLE 41.

Food Materials and Table and Kitchen Wastes in Dietary of a Jeweler's Family During Thirty Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOODS.							
<i>Beef.</i>	%	%	%	Grams.*	Grams.	Grams.	Grams
Shoulder, - - -	19.5	15.6	—	2,297	448	358	—
Sirloin, - - -	18.5	20.5	—	2,159	400	443	—
Shoulder clod, - -	19.5	15.6	—	928	181	145	—
Suet, - - -	0.9	94.6	—	322	3	305	—
Canned, corned, -	26.7	17.1	—	2,193	586	375	—
Total, - - -				7,899	1,618	1,626	—
<i>Mutton.</i>							
Fore quarter, - -	17.0	29.9	—	701	119	210	—
Total, - - -				701	119	210	—
<i>Lamb.</i>							
Leg, - - -	18.9	15.3	—	978	185	150	—
Fore quarter, - -	18.1	25.8	—	3,116	564	804	—
Total, - - -				4,094	749	954	—
<i>Pork.</i>							
Ham, salted, smoked,	16.7	39.1	—	320	53	125	—
Pork, salted, - -	0.9	82.8	—	448	4	371	—
Lard, - - -	—	90.0	—	500	—	450	—
Total, - - -				1,268	57	946	—
Total meats, - -				13,962	2,543	3,736	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 41.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
<i>Fish.</i>	%	%	%	Grams.*	Grams.	Grams.	Grams
Mackerel, - - -	18.2	7.1	—	1,007	183	72	—
Cod, salted, - - -	21.4	0.4	—	1,370	293	5	—
Clams, canned, - -	10.4	0.8	3.0	1,245	130	10	37
Total, - - -				3,622	606	87	37
<i>Dairy Products, Etc.</i>							
Butter, - - -	—	85.0	—	4,670	—	3,969	—
Milk, <i>a</i> - - -	3.4	4.3	4.8	26,137	888	1,124	1,255
Total, - - -				30,807	888	5,093	1,255
Oleomargarine, - -	—	85.0	—	231	—	196	—
Eggs, - - -	14.9	10.5	—	1,783	266	187	—
Total animal foods,				50,405	4,303	9,299	1,292
VEGETABLE FOODS.							
Wheat flour, - - -	11.0	1.1	74.9	1,343	148	15	1,006
Wheat bread, <i>a</i> - -	10.5	1.5	54.6	8,428	885	126	4,602
Wheat rolls, <i>a</i> - -	8.6	9.4	56.7	12,186	1,048	1,146	6,910
Coffee cake, <i>a</i> - -	9.0	6.8	55.4	2,185	197	149	1,211
Cake, <i>a</i> - - -	7.7	14.7	60.3	4,060	313	597	2,448
Cream crackers, <i>a</i> -	9.3	13.1	69.2	399	37	52	276
Graham crackers, -	9.8	13.6	69.7	247	24	34	172
Tapioca and farina, -	—	—	97.8	697	—	—	682
Sugar, - - -	—	—	97.8	9,464	—	—	9,256
Molasses, - - -	—	—	73.1	171	—	—	125
Lima beans, - - -	7.1	0.7	22.0	6,004	426	42	1,321
Green corn, - - -	2.8	1.1	14.2	11,202	314	123	1,591
Potatoes, - - -	2.1	0.1	17.9	16,971	356	17	3,038
Sweet potatoes, - -	1.5	0.4	26.0	11,202	168	45	2,913
Tomatoes, - - -	0.8	0.4	2.5	17,067	137	68	427
Apples, pears & peaches	0.3	0.4	15.9	39,848	120	159	6,336
Muskmellon, - - -	1.4	0.2	20.5	4,043	57	8	829
Bananas, - - -	1.4	1.4	29.8	527	7	7	157
Grapes, - - -	1.6	1.7	21.3	5,833	93	99	1,243
Total, - - -				151,877	4,330	2,687	44,543
Total animal and veg- etable foods pur- chased, - - -				202,282	8,633	11,986	45,835
TABLE & KITCHEN WASTE, <i>a</i>	33.3	39.1	20.4	2,258	752	884	461

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 42.

Weights and Percentages of Food Materials and of Nutritive Ingredients Used in Dietary of a Jeweler's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fats.	Carbo- hydrates.		Protein.	Fats.	Carbo- hydrates.
<i>For Family, 30 Days.</i>	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -	13,962	2,543	3,736	—	30.8	5.7	8.2	—
Fish, - - -	3,622	606	87	37	8.0	1.3	.2	.1
Dairy { Butter, - - -	4,670	—	3,969	—	10.3	—	8.8	—
products, { Milk, - - -	26,137	888	1,124	1,255	57.6	2.0	2.5	2.8
{ Total, - - -	30,807	888	5,093	1,255	67.9	2.0	11.3	2.8
Oleomargarine, - - -	231	—	196	—	.5	—	.4	—
Eggs, - - -	1,783	266	187	—	3.9	.6	.4	—
Total animal food, -	50,405	4,303	9,299	1,292	111.1	9.6	20.5	2.9
Vegetable food, -	151,877	4,330	2,687	44,543	334.8	9.5	5.9	98.2
Total food, - - -	202,282	8,633	11,986	45,835	445.9	19.1	26.4	101.1
<i>Per Man per Day.</i>								
Meats, etc., - - -	147	27	39	—	.324	.06	.086	—
Fish, - - -	38	6	1	—	.084	.013	.002	—
Dairy { Butter, - - -	49	—	42	—	.108	—	.093	—
products, { Milk, - - -	275	9	12	13	.606	.020	.027	.029
{ Total, - - -	324	9	54	13	.714	.020	.120	.029
Oleomargarine, - - -	2	—	2	—	.004	—	.004	—
Eggs, - - -	19	3	2	—	.042	.007	.004	—
Total animal food, -	530	45	98	13	1.168	.100	.216	.029
Vegetable food, -	1,599	46	28	468	3.525	.101	.062	1.032
Total food, - - -	2,129	91	126	481	4.693	.201	.278	1.061
<i>Percentages of Total Food Purchased.</i>	%	%	%	%				
Meats, etc., - - -	6.9	29.5	31.2	—	—	—	—	—
Fish, - - -	1.8	7.0	0.7	0.1	—	—	—	—
Dairy { Butter, - - -	2.3	—	33.1	—	—	—	—	—
products, { Milk, - - -	12.9	10.3	9.4	2.7	—	—	—	—
{ Total, - - -	15.2	10.3	42.5	2.7	—	—	—	—
Oleomargarine, - - -	0.1	—	1.6	—	—	—	—	—
Eggs, - - -	0.9	3.1	1.6	—	—	—	—	—
Total animal food, -	24.9	49.9	77.6	2.8	—	—	—	—
Vegetable food, -	75.1	50.1	22.4	97.2	—	—	—	—
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 43.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Jeweler's Family.

				NUTRIENTS.			Potential Energy.
				Protein.	Fats.	Carbo- hydrates.	
				Gram s.	Grams.	Grams.	Calories.
<i>For Family, 30 Days.</i>							
Food purchased,	Animal, - - -			4,303	9,299	1,292	109,420
	Vegetable, - - -			4,330	2,687	44,543	225,370
Waste, - - -	Total, - - -			8,633	11,986	45,835	334,790
	Animal, - - -			708	857	—	10,875
Food actually eaten,	Vegetable, - - -			44	27	461	2,320
	Total, - - -			752	884	461	13,195
Food actually eaten,	Animal, - - -			3,595	8,442	1,292	98,545
	Vegetable, - - -			4,286	2,660	44,082	223,050
Food actually eaten,	Total, - - -			7,881	11,102	45,374	321,595
<i>Per Man per Day.</i>							
Food purchased,	Animal, - - -			45	98	14	1,150
	Vegetable, - - -			46	28	469	2,375
Waste, - - -	Total, - - -			91	126	483	3,525
	Animal, - - -			8	9	—	115
Food actually eaten,	Vegetable, - - -			—	—	5	25
	Total, - - -			8	9	5	140
Food actually eaten,	Animal, - - -			38	89	14	1,035
	Vegetable, - - -			45	28	464	2,350
Food actually eaten,	Total, - - -			83	117	478	3,385
<i>Percentages of Total Food Purchased.</i>				%	%	%	%
Food purchased,	Animal, - - -			49.9	77.6	2.8	32.7
	Vegetable, - - -			50.1	22.4	97.2	67.3
Waste, - - -	Total, - - -			100.0	100.0	100.0	100.0
	Animal, - - -			8.2	7.2	—	3.2
Food actually eaten,	Vegetable, - - -			0.5	0.2	1.0	0.7
	Total, - - -			8.7	7.4	1.0	3.9
Food actually eaten,	Animal, - - -			41.6	70.4	2.8	29.5
	Vegetable, - - -			49.7	22.2	96.2	66.6
Food actually eaten,	Total, - - -			91.3	92.6	99.0	96.1

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A BLACKSMITH'S FAMILY.

The study began Nov. 11, 1891, and continued 30 days. The family was as follows:—

Man (blacksmith), about 40 years old.

Woman, about 35 (assumed = .8 of one man).

Two boys, 8 to 10 (assumed = $2 \times .7$ of one man).

The meals taken were equivalent to 288 meals, or 96 days for one man.

TABLE 44.

Food Materials and Table and Kitchen Wastes in the Dietary.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams.	Grams.
<i>Beef.</i>							
Round, - - -	18.0	12.3	—	1,361	245	167	—
Ribs, - - -	12.2	27.9	—	2,863	349	799	—
Total, - - -				4,224	594	966	—
<i>Lamb.</i>							
Leg, - - -	15.5	12.6	—	1,814	281	229	—
Total, - - -				1,814	281	229	—
<i>Pork.</i>							
Spare rib, - -	13.3	23.9	—	5,273	702	1,260	—
Ham, smoked, -	14.8	34.6	—	6,690	990	2,315	—
Lard, - - -	—	90.0	—	3,969	—	3,572	—
Pork, salt, - -	0.9	82.8	—	1,191	11	986	—
Sausage, - - -	13.8	42.8	—	4,621	638	1,978	—
Total, - - -				21,744	2,341	10,111	—
<i>Poultry.</i>							
Chicken, - - -	15.1	1.2	—	2,041	308	24	—
Total, - - -				2,041	308	24	—
Total meats, - -				29,823	3,524	11,330	—
<i>Fish.</i>							
Cod, salt, - - -	16.0	0.4	—	1,361	218	5	—
Oysters, - - -	6.3	1.6	4.0	907	57	15	36
Total, - - -				2,268	275	20	36

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 44.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
<i>Dairy Products, Etc.</i>	%	%	%	Grams.*	Grams	Grams.	Grams.
Butter, - - -	—	85.0	—	3,487	—	2,964	—
Milk, <i>a</i> - - -	3.6	4.8	3.8	33,962	1,223	1,630	1,291
Milk, skimmed, <i>a</i> , -	3.4	3.6	4.3	7,711	262	278	332
Total, - - -				45,160	1,485	4,872	1,623
Eggs, - - -	12.1	10.2	—	387	47	39	—
Total, - - -				387	47	39	—
Mince meat, <i>a</i> - -	3.4	5.0	34.1	2,325	79	116	793
Total, - - -				2,325	79	116	793
Total animal food,				79,963	5,410	16,377	2,452
VEGETABLE FOODS.							
Potatoes (15% refuse),	2.1	0.1	17.9	33,543	704	34	6,005
Turnips (30% refuse),	1.2	0.2	8.2	873	10	2	72
Onions (10% refuse),	1.4	0.3	10.1	1,965	28	6	198
Cabbage (15.5% refuse),	1.5	0.2	4.6	10,948	164	22	504
Beans, dried, - -	23.1	2.0	59.2	907	210	18	537
Apples (25% refuse), -	0.3	0.4	15.9	7,825	23	31	1,244
Cranberries, - -	0.4	0.9	10.9	220	1	2	24
Rice, - - -	7.4	0.4	79.4	340	25	1	270
Maize meal, - - -	9.2	3.8	70.6	879	81	33	621
Rye flour, - - -	6.7	0.8	78.7	794	53	6	625
Wheat flour, <i>a</i> - -	13.7	1.2	72.1	21,546	2,952	259	15,535
Buckwheat, - - -	6.9	1.4	76.1	1,247	86	17	949
Oyster crackers, -	11.3	0.8	77.5	794	90	38	615
Sugar, - - -	—	—	97.8	8,826	—	—	8,632
Raisins, - - -	2.7	0.7	71.6	1,219	33	9	873
Total vegetable food,				91,926	4,460	478	36,704
Total animal and vegetable food pur- chased, - - -				171,889	9,870	16,855	39,156
TABLE* AND KITCHEN WASTES, <i>a</i> - -	21.7	31.3	41.8	1,492	323	467	623

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 45.

Weights and Percentages of Food Materials and of Nutritive Ingredients Used in Dietary of a Blacksmith's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fats.	Carbo- hydrates.		Protein.	Fats.	Carbo- hydrates.
<i>For Family, 30 Days.</i>	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -	29,823	3,524	11,330	—	65	8	25	—
Fish, - - - - -	2,268	275	20	36	5	1	—	—
Dairy products,	Butter, - - -	3,487	2,964	—	8	—	7	—
	Milk, - - - -	33,962	1,223	1,630	1,291	75	3	3
	Milk, skim'd, -	7,711	262	278	332	17	1	1
	Total, - - -	45,160	1,485	4,872	1,623	100	3	11
Eggs, - - - - -	387	47	39	—	1	—	—	—
Mince meat, - - -	2,325	79	116	793	5	—	—	1
Total animal food, -	79,963	5,410	16,377	2,452	176	12	36	5
Vegetable food, - -	91,926	4,460	478	36,704	203	10	1	81
Total animal and vege- table food, - - -	171,889	9,870	16,855	39,156	379	22	37	86
<i>Per Man per Day.</i>								
Meats, - - - - -	310	36.7	118.0	—	.677	.080	.260	—
Fish, - - - - -	24	2.9	0.2	0.3	.052	.006	—	.001
Dairy products,	Butter, - - -	36	30.9	—	.083	—	.068	—
	Milk, - - - -	354	12.7	17.0	.781	.028	.038	.029
	Milk, skim'd, -	80	2.7	2.9	.177	.006	.006	.008
	Total, - - -	470	15.4	50.8	1.041	.034	.112	.037
Eggs - - - - -	4	0.5	0.4	—	.010	.001	.001	—
Mince meat, - - -	24	0.8	1.2	8.3	.052	.002	.002	.018
Total animal food, -	832	56.3	170.6	25.5	1.832	.123	.375	.056
Vegetable food, - -	958	46.5	4.9	382.3	2.115	.104	.011	.842
Total food, - - - -	1,790	102.8	175.5	407.8	3.947	.227	.386	.898
<i>Percentage of Total Food.</i>	%	%	%	%				
Meats, etc., - - -	17.4	35.8	67.2	—	—	—	—	—
Fish, - - - - -	1.3	2.8	.1	—	—	—	—	—
Dairy products,	Butter, - - -	2.0	—	17.6	—	—	—	—
	Milk, - - - -	19.7	12.4	9.7	3.2	—	—	—
	Milk, skim'd, -	4.6	2.6	1.7	.8	—	—	—
	Total, - - -	26.3	15.0	29.0	4.0	—	—	—
Eggs, - - - - -	0.2	0.4	0.2	—	—	—	—	—
Mince meat, - - -	1.3	0.8	0.7	2.0	—	—	—	—
Total animal food, -	46.5	54.8	97.2	6.0	—	—	—	—
Vegetable food, - -	53.5	45.2	2.8	94.0	—	—	—	—
Total food, - - - -	100.0	100.0	100.0	100.0	—	—	—	—

* 10.3 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 435.6 grams.

TABLE 46.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Blacksmith's Family.

				NUTRIENTS.			Potential Energy.
				Protein.	Fats.	Carbo- hydrates.	
				Grams.*	Grams.	Grams.	Calories.
<i>For Family, 30 Days.</i>							
Food purchased,	Animal, - - -			5,410	16,377	2,452	184,540
	Vegetable, - - -			4,460	478	36,704	173,215
	Total, - - -			9,870	16,855	39,156	357,755
Waste, - - -	Animal, - - -			248	459	—	5,285
	Vegetable, - - -			75	8	623	2,935
	Total, - - -			323	467	623	8,220
Food actually eaten,	Animal, - - -			5,162	15,918	2,452	179,255
	Vegetable, - - -			4,385	470	36,081	170,280
	Total, - - -			9,547	16,388	38,533	349,535
<i>Per Man per Day.</i>							
Food purchased,	Animal, - - -			56	171	26	1,920
	Vegetable, - - -			47	5	382	1,805
	Total, - - -			103	176	408	3,725
Waste, - - -	Animal, - - -			2	5	—	55
	Vegetable, - - -			1	—	7	30
	Total, - - -			3	5	7	85
Food actually eaten,	Animal, - - -			54	166	26	1,865
	Vegetable, - - -			46	5	375	1,775
	Total, - - -			100	171	401	3,640
<i>Percentages of Total Food Purchased.</i>				%	%	%	%
Food purchased,	Animal, - - -			54.8	97.2	6.0	51.5
	Vegetable, - - -			45.2	2.8	94.0	48.5
	Total, - - -			100.0	100.0	100.0	100.0
Waste, - - -	Animal, - - -			2.5	2.8	—	1.5
	Vegetable, - - -			0.8	0.0	1.6	0.8
	Total, - - -			3.3	2.8	1.8	2.3
Food actually eaten,	Animal, - - -			52.3	94.4	6.3	50.0
	Vegetable, - - -			44.4	2.8	92.1	47.7
	Total, - - -			96.7	97.2	98.4	97.7

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A MACHINIST'S FAMILY.

The study began Nov. 16, 1891, and continued 30 days. The family was as follows:—

Man (machinist), 50 years old, at work.

Woman, 45 years old (assumed = .8 of one man).

Three daughters, 14 to 20 years (assumed = $3 \times .8$ of one man).

The meals taken were equivalent to 383 meals, or 128 days for one man.

TABLE 47.

Food Materials and Table and Kitchen Wastes in Dietary of a Machinist's Family During Thirty Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
<i>Beef.</i>							
Round (no bone), -	20.5	10.1	—	340	69	34	—
Round, - - -	18.0	12.3	—	1,304	235	160	—
Ribs, - - -	12.2	27.9	—	2,041	249	569	—
Shoulder clod, -	17.0	13.7	—	3,062	520	419	—
Total, - - -				6,747	1,073	1,182	—
<i>Veal.</i>							
Chops, - - -	18.3	5.5	—	680	124	37	—
Total, - - -				680	124	37	—
<i>Pork.</i>							
Shoulder, - - -	13.6	28.0	—	2,268	309	635	—
Chops, - - -	13.3	23.9	—	3,685	490	881	—
Ham, smoked, -	14.8	34.6	—	5,415	802	1,874	—
Salt, fat, - - -	0.9	82.8	—	1,248	11	1,033	—
Pigs' feet, a -	10.7	10.1	—	3,742	400	378	—
Sausage, - - -	13.8	42.8	—	3,402	470	1,456	—
Bologna, - - -	18.8	15.8	—	2,041	384	323	—
Lard, - - -	—	90.0	—	3,657	—	3,291	—
Total, - - -				25,458	2,866	9,871	—
<i>Poultry.</i>							
Chicken, - - -	15.1	1.2	—	1,814	274	22	—
Gosling, a - -	13.4	29.8	—	3,629	486	1,082	—
Total, - - -				5,443	760	1,104	—
Total meats, -				38,328	4,823	12,194	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 47.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
<i>Fish.</i>	%	%	%	Grams*	Grams	Grams	Grams
Haddock, - - -	8.2	0.2	—	1,077	88	2	—
Total fish, - -				1,077	88	2	—
<i>Dairy Products, Etc.</i>							
Butter, - - - -	—	85.0	—	5,046	—	4,289	—
Milk, <i>a</i> - - - -	3.3	5.4	4.0	47,343	1,563	2,557	1,894
Total, - - - -				52,389	1,563	6,846	1,894
Eggs, - - - -	12.1	10.2	—	1,286	156	131	—
Total, - - - -				1,286	156	131	—
Total animal food, -				93,080	6,630	19,173	1,894
<i>VEGETABLE FOODS.</i>							
Potatoes (15 % refuse), -	2.1	0.1	17.9	29,976	630	30	5,367
Potatoes, sweet, - -	1.5	0.4	26.0	3,374	51	14	877
Onions (10 % refuse), -	1.4	0.3	10.1	995	14	3	101
Cabbage (15 % refuse), -	1.5	0.2	4.6	958	14	2	44
Turnips, - - - -	1.2	0.2	8.2	3,572	43	7	293
Beans, dried, - - -	23.1	2.0	59.2	227	52	5	134
Split peas, <i>a</i> - - -	26.3	0.9	61.4	1,729	455	16	1,062
Pears and apples (25 % refuse), - - - -	0.3	0.4	15.9	18,541	56	74	2,948
Cranberries, - - -	0.4	0.9	10.9	440	2	4	48
Raisins and prunes, -	2.7	0.7	71.6	653	18	5	468
Rice, - - - -	7.4	0.4	79.4	680	50	3	540
Farina and sago, - -	—	—	97.8	993	—	—	971
Oatmeal, - - - -	14.7	7.1	68.4	1,134	167	81	776
Buckwheat flour, - -	6.9	1.4	76.1	3,062	211	43	2,330
Rye flour, - - - -	6.7	0.8	78.7	1,191	80	10	937
Wheat flour, <i>a</i> - - -	13.8	1.2	71.7	27,159	3,748	326	19,472
Bread, - - - -	9.1	1.6	56.0	3,232	294	52	1,810
Drop cakes, <i>a</i> - - -	7.7	14.7	60.3	1,814	140	267	1,094
Sugar, - - - -	—	—	97.8	12,573	—	—	12,295
Molasses, - - - -	—	—	73.1	57	—	—	42
Chocolate, - - - -	6.2	21.0	69.0	340	21	71	235
Cream crackers, <i>a</i> -	9.3	13.1	69.2	1,247	116	163	863
Total vegetable food,				113,947	6,162	1,176	52,707
Total animal & vegetable food purchased, -				207,027	12,792	20,349	54,601
<i>TABLE AND KITCHEN WASTES, - - - -</i>	9.4	29.8	55.7	1,367	128	408	761

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 48.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Machinist's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fats.	Carbo- hydrates.		Protein.	Fats.	Carbo- hydrates.
<i>For Family, 30 Days.</i>	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, - - - -	38,328	4,823	12,194	—	85	11	27	—
Fish, - - - -	1,077	88	2	—	2	—	—	—
Dairy products, { Butter, - - - -	5,046	—	4,289	—	11	—	9	—
{ Milk, - - - -	47,343	1,563	2,557	1,894	104	3	6	4
{ Total, - - - -	52,389	1,563	6,846	1,894	115	3	15	4
Eggs, - - - -	1,286	156	131	—	3	—	—	—
Total animal food, -	93,080	6,630	19,173	1,894	205	14	42	4
Vegetable food, -	113,947	6,162	1,176	52,707	251	14	3	116
Total animal and vegetable food, -	207,027	12,792	20,349	54,601	456	28	45	120
<i>Per Man per Day.</i>								
Meats, - - - -	300	37.7	95.3	—	.667	.083	.210	—
Fish, - - - -	8	.7	—	—	.015	.001	—	—
Dairy products, { Butter, - - - -	39	—	33.5	—	.085	—	.074	—
{ Milk, - - - -	370	12.2	20.0	14.8	.812	.027	.044	.032
{ Total, - - - -	409	12.2	53.5	14.8	.897	.027	.118	.032
Eggs, - - - -	10	1.2	1.0	—	.023	.003	.002	—
Total animal food, -	727	51.8	149.8	14.8	1.602	.114	.330	.032
Vegetable food, -	890	48.1	9.2	411.8	1.960	.106	.020	.908
Total food, - - -	1,617	99.9	159.0	426.6	3.562	.220	.350	.940
<i>Percentages of Total Food Purchased.</i>	%	%	%	%				
Meats, etc., - - -	18.5	37.7	59.9	—	—	—	—	—
Fish, - - - -	.5	.7	—	—	—	—	—	—
Dairy products, { Butter, - - - -	2.4	—	21.1	—	—	—	—	—
{ Milk, - - - -	22.9	12.2	12.6	3.5	—	—	—	—
{ Total, - - - -	25.3	12.2	33.7	3.5	—	—	—	—
Eggs, - - - -	.6	1.2	.6	—	—	—	—	—
Total animal food, -	44.9	51.8	94.2	3.5	—	—	—	—
Vegetable food, -	55.1	48.2	5.8	96.5	—	—	—	—
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams=3.5 ounces, or .22 pounds. 1 ounce=28.35 grams. 1 pound=453.6 grams.

TABLE 49.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Machinist's Family.

				NUTRIENTS.			Potential Energy.
				Protein.	Fats.	Carbo- hydrates.	
				Grams.*	Grams.	Grams.	Calories.
<i>For Family, 30 Days.</i>							
Food purchased.	Animal, - - -			6,630	19,173	1,894	213,255
	Vegetable, - - -			6,162	1,176	52,707	252,300
	Total, - - -			12,792	20,349	54,601	465,555
Waste, - - -	Animal, - - -			39	391	—	3,795
	Vegetable, - - -			89	17	761	3,645
	Total, - - -			128	408	761	7,440
Food actually eaten,	Animal, - - -			6,591	18,782	1,894	209,460
	Vegetable, - - -			6,073	1,159	51,946	248,655
	Total, - - -			12,664	19,941	53,840	458,115
<i>Per Man per Day.</i>							
Food purchased,	Animal, - - -			52	150	15	1,670
	Vegetable, - - -			48	9	412	1,970
	Total, - - -			100	159	427	3,640
Waste, - - -	Animal, - - -			—	3	—	30
	Vegetable, - - -			1	—	6	30
	Total, - - -			1	3	6	60
Food actually eaten,	Animal, - - -			52	147	15	1,640
	Vegetable, - - -			47	9	406	1,940
	Total, - - -			99	156	421	3,580
<i>Percentage of Total Food Purchased.</i>				%	%	%	%
Food purchased,	Animal, - - -			51.8	94.2	3.5	45.8
	Vegetable, - - -			48.2	5.8	96.5	54.2
	Total, - - -			100.0	100.0	100.0	100.0
Waste, - - -	Animal, - - -			0.3	1.9	—	0.8
	Vegetable, - - -			0.7	0.1	1.4	0.8
	Total, - - -			1.0	2.0	1.4	1.6
Food actually eaten,	Animal, - - -			51.3	92.3	3.5	45.0
	Vegetable, - - -			47.7	5.7	95.1	53.4
	Total, - - -			99.0	98.0	98.6	98.4

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A MASON'S FAMILY.

The study began Nov. 26, 1892, and continued 28 days. The family was as follows:—

Man about 28 years old (mason), at work three of the four weeks.

Woman of about same age (assumed = .8 of one man).

Child of 7 months (assumed = .25 of one man).

The meals taken were equivalent to 172 meals, or 57 days for one man.

TABLE 50.

Food Materials and Table and Kitchen Wastes in Dietary of a Mason's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOODS.							
<i>Beef.</i>	%	%	%	Grams*	Grams	Grams	Grams
Shoulder, - - -	17.0	13.7	—	4,100	697	561	—
Round, - - -	18.0	12.3	—	1,250	225	154	—
Leg free from bone, -	21.0	5.7	—	880	185	50	—
Dried Beef, - - -	28.8	4.4	—	260	75	11	—
Bologna sausage, - -	18.8	15.8	—	280	53	44	—
Total, - - -				6,770	1,235	820	—
<i>Pork.</i>							
Spare rib, a - -	17.0	30.4	—	2,520	428	770	—
Sausage, - - -	13.8	42.8	—	1,560	215	668	—
Ham (smoked), - -	14.8	34.6	—	2,520	373	872	—
Salt pork, - - -	.9	82.8	—	2,310	20	1,913	—
Lard, - - -	—	99.8	—	940	—	938	—
Total, - - -				9,850	1,036	5,161	—
<i>Fish, Etc.</i>							
Canned salmon, - -	20.1	15.7	—	2,420	486	380	—
Pickled herring, - -	18.5	11.0	—	1,990	358	219	—
Clams in shell, - -	2.1	1.0	1.3	1,730	36	2	22
Total, - - -				6,140	880	601	22

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 50.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
<i>Dairy Products, Etc.</i>	%	%	%	Grams*	Grams	Grams	Grams
Butter, - - -	—	85.0	—	1,130	—	1,130	—
Milk, - - -	3.6	4.0	4.7	15,880	569	635	746
Total, - - -				17,210	569	1,765	746
Eggs, - - -	12.1	10.2	—	1,390	168	142	—
Total animal food, -				41,360	3,888	8,489	768
VEGETABLE FOODS.							
Potatoes (15 % refuse), -	2.1	.1	17.9	18,500	389	18	3,312
Sweet potatoes (12.5 % refuse), - - -	1.5	.4	26.0	1,370	21	5	382
Onions (10 % refuse), -	1.4	.3	10.1	510	6	2	52
Turnips (30 % refuse), -	1.2	.2	8.2	3,140	38	6	257
Apples (25 % refuse), -	.3	.4	15.9	3,620	11	14	576
Raisins and prunes, -	2.7	.7	71.6	1,370	37	9	981
Starch, etc., - - -	—	—	97.8	760	—	—	743
Oatmeal, - - -	14.7	7.1	68.4	210	32	15	146
Flour, <i>a</i> - - -	13.2	1.2	73.1	9,530	1,258	114	6,966
Rye flour, <i>a</i> - - -	12.0	1.2	74.2	3,520	422	42	2,612
Sugar, "extra C," <i>a</i> -	—	—	95.0	2,280	—	—	2,166
Sugar, granulated, <i>a</i> -	—	—	100.0	5,500	—	—	5,500
Total, - - -				50,310	2,214	216	21,527
Total animal and veg- etable foods pur- chased, - - -				91,670	6,102	8,705	22,295
TABLE AND KITCHEN WASTES, - - -	12.9	21.6	62.1	1,244	161	269	772

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 51.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Mason's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fat.	Carbo- hydrates.		Protein.	Fat.	Carbo- hydrates.
<i>For Family, 28 Days.</i>	Grams.*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -	16,620	2,271	5,981	—	36.6	5.0	13.2	—
Fish, etc., - - -	6,140	880	601	22	13.5	1.9	1.3	—
Dairy products, {	Butter, -	1,330	1,130	—	2.9	—	2.5	—
	Milk, -	15,880	569	635	35.0	1.3	1.4	1.6
	Total, -	17,210	569	1,765	37.9	1.3	3.9	1.6
Eggs, - - -	1,390	168	142	—	3.1	.4	.3	—
Total animal food, -	41,360	3,888	8,480	768	91.1	8.6	18.7	1.6
Vegetable food, -	50,310	2,214	216	21,527	110.9	4.9	.5	47.4
Total food, - - -	91,670	6,102	8,705	22,295	202.0	13.5	19.2	49.0
<i>Per Man per Day.</i>								
Meats, etc., - - -	292	40	105	—	.65	.09	.23	—
Fish, etc., - - -	108	15	10	—	.23	.03	.02	—
Dairy products, {	Butter, -	23	20	—	.05	—	.04	—
	Milk, -	279	10	11	.62	.02	.03	.03
	Total, -	302	10	31	.67	.02	.07	.03
Eggs, - - -	24	3	3	—	.05	.01	.01	—
Total animal food, -	726	68	149	13	1.60	.15	.33	.03
Vegetable food, -	883	39	4	378	1.94	.09	—	.83
Total food, - - -	1,609	107	153	391	3.54	.24	.33	.86
<i>Percentages of Total Food Purchased.</i>	%	%	%	%				
Meats, etc., - - -	18.2	37.3	68.7	—	—	—	—	—
Fish, etc., - - -	6.7	14.4	6.9	—	—	—	—	—
Dairy products, {	Butter, -	1.4	13.0	—	—	—	—	—
	Milk, -	17.4	9.3	3.5	—	—	—	—
	Total, -	18.8	9.3	3.5	—	—	—	—
Eggs, - - -	1.4	2.7	1.6	—	—	—	—	—
Total animal food, -	45.1	63.7	97.5	3.4	—	—	—	—
Vegetable food, -	54.9	36.3	2.5	96.6	—	—	—	—
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 52.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Mason's Family.

				NUTRIENTS.			Potential Energy.
				Protein.	Fat.	Carbo- hydrates.	
<i>For Family, 28 Days.</i>				Grams*	Grams	Grams.	Calor's.
Food purchased,	-	Animal,	- -	3,888	8,489	768	98,040
		Vegetable,	- -	2,214	216	21,527	99,350
Waste,	- - -	Total,	- - -	6,102	8,705	22,295	197,390
		Animal,	- - -	144	206	—	3,060
		Vegetable,	- - -	17	3	772	3,260
		Total,	- - -	161	269	772	6,320
Food actually eaten,		Animal,	- - -	3,744	8,223	768	94,980
		Vegetable,	- - -	2,197	213	20,755	96,090
		Total,	- - -	5,941	8,436	21,523	191,070
<i>Per Man per Day.</i>							
Food purchased	-	Animal,	- -	68	149	13	1,720
		Vegetable,	- -	39	4	378	1,750
Waste,	- - -	Total,	- - -	107	153	391	3,470
		Animal,	- - -	3	5	—	60
		Vegetable,	- - -	—	—	16	60
		Total,	- - -	3	5	16	120
Food actually eaten,		Animal,	- - -	65	144	13	1,660
		Vegetable,	- - -	39	4	362	1,690
		Total,	- - -	104	148	375	3,350
<i>Percentage of Total Food Purchased.</i>				%	%	%	%
Food purchased,	-	Animal,	- -	63.7	97.5	3.4	49.7
		Vegetable,	- -	36.3	2.5	96.6	50.3
Waste,	- - -	Total,	- - -	100.0	100.0	100.0	100.0
		Animal,	- - -	2.3	3.1	—	1.5
		Vegetable,	- - -	.3	—	3.5	1.6
		Total,	- - -	2.6	3.1	3.5	3.1
Food actually eaten,		Animal,	- - -	61.4	94.5	3.4	48.2
		Vegetable,	- - -	36.0	2.4	93.1	48.7
		Total,	- - -	97.4	96.9	96.5	96.9

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A CARPENTER'S FAMILY.

The study began Nov. 25, 1892, and continued 28 days. The family was as follows:—

Man (carpenter), about 25 years old, at work.

Woman, about 25 years old (assumed = .8 of one man).

Boy, about 2 years old (assumed = .5 of one man).

The meals taken were equivalent to 205 meals, or 68 days for one man.

TABLE 53.

Food Materials and Table and Kitchen Wastes in Dietary of a Carpenter's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
<i>Beef.</i>							
Shoulder, - - -	17.0	13.7	—	3,420	581	469	—
Leg free from bone, -	21.0	5.7	—	480	101	27	—
Sirloin, - - -	15.0	16.4	—	850	128	139	—
Round, - - -	18.0	12.3	—	850	153	105	—
Ribs, - - -	12.2	27.9	—	1,310	160	366	—
Suet, - - -	.9	94.6	—	90	1	85	—
Frankfort sausage, -	18.8	15.8	—	990	186	156	—
Total, - - -				7,990	1,310	1,347	—
<i>Veal.</i>							
Shoulder, - - -	18.3	5.5	—	1,930	353	106	—
Total, - - -				1,930	353	106	—
<i>Pork.</i>							
Chops, a - - -	17.0	30.4	—	6,950	1,182	2,113	—
Sausage, - - -	13.8	42.8	—	2,520	348	1,079	—
Ham, smoked, - - -	14.8	34.6	—	3,240	480	1,121	—
Salt pork, - - -	.9	82.8	—	70	1	58	—
Lard, a - - -	—	99.8	—	1,230	—	1,228	—
Total, - - -				14,010	2,011	5,599	—
<i>Poultry.</i>							
Chicken, - - -	15.1	1.2	—	1,360	205	16	—
Total, - - -				1,360	205	16	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 53.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
<i>Fish.</i>	%	%	%	Grams*	Grams	Grams	Grams
Boneless salt cod, -	22.2	.3	—	440	98	1	—
Total, - - -				440	98	1	—
<i>Dairy Products, Etc.</i>							
Butter, - - -	—	85.0	—	2,070	—	1,760	—
Whole milk, <i>a</i> - -	4.4	5.8	4.4	15,860	698	920	698
Skimmed milk, <i>a</i> - -	3.9	.5	4.6	18,140	708	91	835
Total, - - -				36,070	1,406	2,771	1,533
Eggs, - - - -	12.1	10.2	—	1,260	153	129	—
Total animal food, -				63,060	5,536	9,969	1,533
VEGETABLE FOODS.							
Potatoes (15 % refuse), -	2.1	.1	17.9	18,530	389	19	3,317
Sweet potatoes (12.5 % refuse), - - -	1.5	.4	26.0	1,400	21	6	364
Onions (10 % refuse), -	1.4	.3	10.1	2,200	31	7	222
Turnips (30 % refuse), -	1.2	.2	8.2	3,900	47	8	320
Cabbage (15 % refuse), -	1.5	.2	4.6	890	13	2	41
Canned squash, - - -	.9	.2	10.1	990	9	2	100
Apples (25 % refuse), -	.3	.4	15.9	10,450	31	42	1,662
Grapes (25 % refuse), -	1.7	1.7	21.3	1,430	24	24	305
Dried Beans, - - -	23.1	2.0	59.2	1,960	453	39	1,160
Starch, etc., - - -	—	—	97.8	520	—	—	509
Rice, - - - -	7.4	.4	79.4	370	27	2	294
Flour, <i>a</i> - - - -	12.2	1.1	72.3	16,010	1,953	176	11,575
Sugar, <i>a</i> - - - -	—	—	100.0	11,170	—	—	11,170
Molasses, <i>a</i> - - -	—	—	72.0	1,790	—	—	1,289
Total vegetable food,				71,610	2,998	327	32,328
Total animal and veg- etable food pur- chased, - - -				134,670	8,534	10,296	33,861
TABLE AND KITCHEN WASTES, - - -	21.6	31.8	42.0	3,653	790	1,161	1,536

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 54.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Carpenter's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fat.	Carbo- hydrates.		Protein.	Fat.	Carbo- hydrates.
<i>For Family, 28 Days.</i>	Grams*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -	25,290	3,879	7,068	—	55.8	8.6	15.6	—
Fish, etc., - - -	440	98	1	—	1.0	.2	—	—
Dairy products, {	Butter, -	2,070	—	1,760	4.5	—	3.9	—
	Milk, -	34,000	1,406	1,011	1,533	75.0	3.1	2.2
Eggs, - - -	Total, -	36,070	1,406	2,771	79.5	3.1	6.1	3.4
		1,260	153	129	2.8	.3	.3	—
Total animal food, -	63,060	5,536	9,969	1,533	139.1	12.2	22.0	3.4
Vegetable food, -	71,610	2,993	327	32,328	157.8	6.6	.7	71.2
Total food, - - -	134,670	8,534	10,296	33,861	296.9	18.8	22.7	74.6
<i>Per Man per Day.</i>								
Meats, etc., - - -	373	57	104	—	.82	.13	.22	—
Fish, etc., - - -	6	1	—	—	.01	—	—	—
Dairy products, {	Butter, -	30	—	26	.07	—	.06	—
	Milk, -	500	21	15	23	1.10	.04	.03
Eggs, - - -	Total, -	530	21	41	23	1.17	.04	.09
		18	2	2	—	.04	.01	.01
Total animal food, -	927	81	147	23	2.04	.18	.32	.05
Vegetable food, -	1,053	44	5	475	2.32	.09	.01	1.05
Total food, - - -	1,980	125	152	498	4.36	.27	.33	1.10
<i>Percentages of Total Food Purchased.</i>	%	%	%	%				
Meats, etc., - - -	18.9	45.5	68.6	—	—	—	—	—
Fish, etc., - - -	.3	1.1	—	—	—	—	—	—
Dairy products, {	Butter, -	1.5	—	17.0	—	—	—	—
	Milk, -	25.2	16.5	9.8	4.5	—	—	—
Eggs, - - -	Total, -	26.7	16.5	26.8	4.5	—	—	—
		.9	1.8	1.3	—	—	—	—
Total animal food, -	46.8	64.9	96.7	4.5	—	—	—	—
Vegetable food, -	53.2	35.1	3.3	95.5	—	—	—	—
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 55.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Carpenter's Family.

				NUTRIENTS.			Potential Energy.
				Protein.	Fats.	Carbo-hydrates.	
				Grams.*	Grams.	Grams.	Calories.
<i>For Family, 28 Days.</i>							
Food purchased,	Animal, - - -			5,536	9,969	1,533	121,690
	Vegetable, - - -			2,998	327	32,328	147,880
	Total, - - -			8,534	10,296	33,861	269,570
Waste, - - -	Animal, - - -			643	1,146	—	13,290
	Vegetable, - - -			147	15	1,536	7,040
	Total, - - -			790	1,161	1,536	20,330
Food actually eaten,	Animal, - - -			4,893	8,823	1,533	108,400
	Vegetable, - - -			2,851	312	30,792	140,840
	Total, - - -			7,744	9,135	32,325	249,240
<i>Per Man per Day.</i>							
Food purchased,	Animal, - - -			81	147	23	1,790
	Vegetable, - - -			44	5	475	2,180
	Total, - - -			125	152	498	3,970
Waste, - - -	Animal, - - -			9	17	—	200
	Vegetable, - - -			2	—	23	100
	Total, - - -			11	17	23	300
Food actually eaten,	Animal, - - -			72	130	23	1,590
	Vegetable, - - -			42	5	452	2,080
	Total, - - -			114	135	475	3,670
<i>Percentage of Total Food Purchased.</i>				%	%	%	%
Food purchased,	Animal, - - -			64.9	96.7	4.5	45.2
	Vegetable, - - -			35.1	3.3	95.5	54.8
	Total, - - -			100.0	100.0	100.0	100.0
Waste, - - -	Animal, - - -			7.6	11.1	—	5.0
	Vegetable, - - -			1.7	0.1	4.5	2.6
	Total, - - -			9.3	11.2	4.5	7.6
Food actually eaten,	Animal, - - -			57.3	85.6	4.5	40.2
	Vegetable, - - -			33.4	3.2	91.0	52.2
	Total, - - -			90.7	88.8	95.5	92.4

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A CARPENTER'S FAMILY.

The study began Nov. 26, 1892, and continued 28 days. The family was as follows:—

Man (carpenter) about 35 years old, at work.

Woman of about same age (assumed = .8 of one man).

Boy about 11 years old (assumed = .7 of one man).

The meals taken were equivalent to 210 meals; or 70 days for one man.

TABLE 56.

Food Materials and Table and Kitchen Wastes in Dietary of a Carpenter's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOODS.	%	%	%	Grams*	Grams	Grams	Grams
<i>Beef.</i>							
Sirloin, - - -	15.0	16.4	—	1,900	285	312	—
Leg, free from bone, -	21.0	5.7	—	4,100	861	234	—
Dried Beef, - - -	28.8	4.4	1.4	230	66	10	3
Frankfort sausage, -	18.8	15.8	—	370	70	58	—
Liver, - - -	20.1	5.4	3.5	450	90	24	16
Total, - - -				7,050	1,372	638	19
<i>Lamb.</i>							
Chop, - - -	16.7	22.1	—	680	114	150	—
<i>Pork.</i>							
Spare rib, a - - -	17.0	30.4	—	1,910	324	580	—
Sausage, - - -	13.8	42.8	—	1,970	272	843	—
Ham, - - -	14.8	34.6	—	1,870	277	647	—
Salt pork, - - -	.9	82.8	—	1,020	9	845	—
Lard, a - - -	—	99.8	—	3,000	—	2,994	—
Total, - - -				9,770	882	5,909	—
<i>Poultry.</i>							
Turkey, free from bone,	23.9	8.7	—	2,210	528	192	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 56.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
<i>Fish.</i>	%	%	%	Grams*	Grams	Grams	Grams
Salt cod, - - -	16.0	.4	—	1,470	235	6	—
Total fish, - -				1,470	235	6	—
<i>Dairy Products, Etc.</i>							
Butter, - - -	—	85.0	—	3,150	—	2,678	—
Milk, - - -	3.6	4.0	4.7	13,830	498	553	650
Cheese, - - -	28.3	35.5	1.8	1,490	422	529	27
Total, - - -				18,470	920	3,760	677
Eggs, - - -	12.1	10.2	—	760	92	78	—
Total, - - -				760	92	78	—
Total animal food, -				40,410	4,143	10,733	696
<i>VEGETABLE FOODS.</i>							
Potatoes (15 % refuse), -	2.1	.1	17.9	31,620	664	32	5,660
Sweet potatoes (12.5 % refuse), - - -	1.5	.4	26.0	2,260	34	8	588
Turnips (30 % refuse), -	1.2	.2	8.2	7,990	96	16	655
Canned squash, - - -	.9	.2	10.1	1,030	9	2	104
Apples (25 % refuse), -	.3	.4	15.9	4,000	12	16	636
Grapes (25 % refuse), -	1.7	1.7	21.3	1,100	19	19	234
Beans, dried, - - -	23.1	2.0	59.2	870	200	17	516
Raisins, - - -	2.7	.7	71.5	430	16	3	303
Starch, - - -	—	—	97.8	280	—	—	279
Rice, - - -	7.4	.4	79.4	150	11	—	119
Mince meat, "None- such," a - - -	4.0	2.2	67.4	1,370	55	30	923
Flour, a - - -	12.0	1.2	74.2	6,920	830	83	5,135
Buckwheat flour, - -	6.9	1.4	76.1	1,300	90	18	989
Bread, - - -	9.1	1.6	56.0	13,690	1,246	219	7,666
Cake, - - -	8.3	10.8	57.6	890	74	96	512
Sugar, extra C, a - -	—	—	95.0	3,730	—	—	3,543
Total vegetable food,	—	—	—	77,630	3,356	559	27,862
Total animal & vegetable food purchased, -	—	—	—	118,040	7,499	11,292	28,558
TABLE AND KITCHEN WASTES, - - -	17.0	29.2	50.1	2,805	477	821	1,405

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 57.

Weights and Percentages of Food Materials and Nutritive Ingredients Used in Dietary of a Carpenter's Family.

KINDS OF FOOD MATERIALS.	WEIGHT IN GRAMS.				WEIGHT IN POUNDS.			
	Food Materials.	Nutrients.			Food Materials.	Nutrients.		
		Protein.	Fats.	Carbo- hydrates.		Protein.	Fats.	Carbo- hydrates.
<i>For Family, 28 Days.</i>	Grams*	Grams	Grams	Grams	Lbs.	Lbs.	Lbs.	Lbs.
Meats, etc., - - -	19,710	2,896	6,889	19	43.6	6.4	15.2	—
Fish, - - -	1,470	235	6	—	3.2	.5	—	—
Dairy products,	{ Butter, - -	3,150	—	2,678	—	6.9	—	5.9
	{ Milk, - -	13,830	498	553	650	30.5	1.1	1.2
	{ Cheese, - -	1,490	422	529	27	3.3	.9	1.2
	{ Total, - -	18,470	920	3,760	677	40.7	2.0	8.3
Eggs, - - -	760	92	78	—	1.7	.2	.2	—
Total animal food, -	40,410	4,143	10,733	696	89.2	9.1	23.7	1.5
Vegetable food, -	77,630	3,356	559	27,862	171.1	7.4	1.2	61.5
Total food, - - -	118,040	7,499	11,292	28,558	260.3	16.5	24.9	63.0
<i>Per Man per Day.</i>								
Meats, - - -	281	42	98	—	.62	.10	.21	—
Fish, - - -	21	3	—	—	.05	—	—	—
Dairy products,	{ Butter, - -	45	—	38	—	.10	—	.08
	{ Milk, - -	198	7	8	9	.44	.02	.02
	{ Cheese, - -	21	6	8	1	.04	.01	.02
	{ Total, - -	264	13	54	10	.58	.03	.12
Eggs, - - -	11	1	1	—	.02	—	—	—
Total animal food, -	577	59	153	10	1.27	.13	.33	.02
Vegetable food, - -	1,109	48	8	398	2.45	.11	.02	.88
Total food, - - -	1,686	107	161	408	3.72	.24	.35	.90
<i>Percentages of Total Food Purchased.</i>	%	%	%	%				
Meats, etc., - - -	16.7	38.6	61.1	—	—	—	—	—
Fish, - - -	1.2	3.1	—	—	—	—	—	—
Dairy products,	{ Butter, - -	2.7	—	23.9	—	—	—	—
	{ Milk, - -	11.7	6.6	4.8	2.3	—	—	—
	{ Cheese, - -	1.2	5.7	4.6	.1	—	—	—
	{ Total, - -	15.6	12.3	33.3	2.4	—	—	—
Eggs, - - -	.7	1.2	.7	—	—	—	—	—
Total animal food, -	34.2	55.2	95.1	2.4	—	—	—	—
Vegetable food, - -	65.8	44.8	4.9	97.6	—	—	—	—
Total food, - - -	100.0	100.0	100.0	100.0	—	—	—	—

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 58.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Carpenter's Family.

				NUTRIENTS.			Potential Energy.
				Protein.	Fats.	Carbo- hydrates.	
				Grams.*	Grams.	Grams.	Calories.
<i>For Family, 28 Days.</i>							
Food purchased,	Animal, - - -			4,143	10,733	696	119,670
	Vegetable, - - -			3,356	559	27,862	133,190
	Total, - - -			7,499	11,292	28,558	252,860
Waste, - - -	Animal, - - -			420	805	—	9,210
	Vegetable, - - -			57	16	1,405	6,110
	Total, - - -			477	821	1,405	15,320
Food actually eaten,	Animal, - - -			3,723	9,928	696	110,460
	Vegetable, - - -			3,299	543	26,457	127,080
	Total, - - -			7,022	10,471	27,153	237,540
<i>Per Man per Day.</i>							
Food purchased,	Animal, - - -			59	153	10	1,710
	Vegetable, - - -			48	8	398	1,900
	Total, - - -			107	161	408	3,610
Waste, - - -	Animal, - - -			6	12	—	140
	Vegetable, - - -			1	—	20	80
	Total, - - -			7	12	20	220
Food actually eaten,	Animal, - - -			53	141	10	1,570
	Vegetable, - - -			47	8	378	1,820
	Total, - - -			100	149	388	3,390
<i>Percentages of Total Food Purchased.</i>				%	%	%	%
Food purchased,	Animal, - - -			55.2	95.1	2.4	47.3
	Vegetable, - - -			44.8	4.9	97.6	52.7
	Total, - - -			100.0	100.0	100.0	100.0
Waste, - - -	Animal, - - -			5.6	7.1	—	3.6
	Vegetable, - - -			0.8	0.1	4.9	2.4
	Total, - - -			6.4	7.2	4.9	6.0
Food actually eaten,	Animal, - - -			49.6	88.0	2.4	43.7
	Vegetable, - - -			44.6	4.8	92.7	50.3
	Total, - - -			93.6	92.8	95.1	94.0

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 59.

Summary of Results of Dietary Studies made by Station.—Food per Man per Day.

	NUTRIENTS.			Potential Energy.
	Protein.	Fat.	Carbo- hydrates.	
	Grams.*	Grams.	Grams.	Calories.
<i>1. Dietary of a Boarding House.†</i>				
Food, - - - { Purchased, - - -	126	188	426	4,010
- - - { Waste, - - -	23	36	25	520
- - - { Eaten, - - -	103	152	401	3,490
<i>2. Dietary of a Chemist's Family.†</i>				
Food purchased, ‡ - - - -	118	103	430	3,210
<i>3. Dietary of a Jeweler's Family.</i>				
Food, - - - { Purchased, - - -	91	126	483	3,530
- - - { Waste, - - -	8	9	5	140
- - - { Eaten, - - -	83	117	478	3,390
<i>4. Dietary of a Blacksmith's Family.</i>				
Food, - - - { Purchased, - - -	103	176	408	3,730
- - - { Waste, - - -	3	5	7	90
- - - { Eaten, - - -	100	171	401	3,640
<i>5. Dietary of a Machinist's Family.</i>				
Food, - - - { Purchased, - - -	100	159	427	3,640
- - - { Waste, - - -	1	3	6	60
- - - { Eaten, - - -	99	156	421	3,580
<i>6. Dietary of a Mason's Family.</i>				
Food, - - - { Purchased, - - -	107	153	391	3,470
- - - { Waste, - - -	3	5	16	120
- - - { Eaten, - - -	104	148	375	3,350
<i>7. Dietary of a Carpenter's Family.</i>				
Food, - - - { Purchased, - - -	125	152	498	3,970
- - - { Waste, - - -	11	17	23	300
- - - { Eaten, - - -	114	135	475	3,670
<i>8. Dietary of a Carpenter's Family.</i>				
Food, - - - { Purchased, - - -	107	161	408	3,610
- - - { Waste, - - -	7	12	20	220
- - - { Eaten, - - -	100	149	388	3,390
Food eaten, - - { Minimum of above, -	83	103	375	3,210
- - { Maximum of above, -	118	171	478	3,640
- - { Average of above, -	103	141	421	3,460
Dietary standards {				
for men at mod- { Voigt (German), - -	118	56	500	3,060
erate work, - { Atwater (American), -	125	125	450	3,560

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

† Report of this Station 1891, pages 99-106.

‡ There was very little "waste" in this dietary.

ECONOMY OF FOOD.

BY W. O. ATWATER.



Food constitutes the chief item of the living expenses of the people, of our agricultural production, and of our export to Europe. Wage-workers and people of moderate incomes generally spend, and must spend, more than half their earnings for food. Nevertheless, they do not understand either the relation of the nutritive value of food to its cost, or its physiological effects. The result is great waste in the purchase and use of food, loss of money and injury to health.

NUTRITIVE VALUES OF FOODS.

A pound of lean beef and a quart of whole milk contain about the same amounts of actually nutritive material. But the pound of beef costs more than the quart of milk, and its nutrients not only differ in number and kind, but are, for ordinary use, more valuable than those of the milk. This illustrates a fundamental fact in the economy of foods, namely, that the differences in the values of different foods depend upon both the kinds and the amounts of the nutritive materials which they contain. Add to this that it is essential for health that the food shall supply the nutrients in the kinds and the proportions required by the body, and that it is likewise important, from a pecuniary standpoint, that the materials be obtained at the minimum cost, and we have the fundamental principles of food economy.

In the last Annual Report of this Station* detailed accounts were given of a series of investigations of the chemical composition and nutritive values of common kinds of food, and of the amounts of food and of nutritive ingredients in a number of dietaries of people in various conditions of life in the United States and in Europe. A preceding chapter in the present report (pp. 135-162,) describes a continuation of the study of

* See also Bulletin No. 6 of the Station on the Chemistry and Economy of Foods, and report of U. S. Fish Commission for 1888 (Washington, 1892), pp. 817-868.

dietaries. The purpose of the present article is to call attention in more detail to some points which bear upon the economical use of food. As the subject is comparatively new to most readers, and this Report will fall into the hands of many who are not familiar with the latest teachings of chemistry and physiology, some explanations may not be out of place.

THE NUTRITIVE INGREDIENTS OF FOOD.

Edible Portion and Refuse.—If the reader will take the pains to notice the next piece of beef that he has to carve for dinner, he will, of course, observe first of all that, along with the meat which is good to eat, there is more or less bone, which, except in so far as it may be used for soup, is of no value for food. The beef, then, may be regarded as consisting of edible portion and refuse. The same is true of fish. In eggs there is a corresponding distinction between shells and the so-called “meat,” and oysters and other shellfish in like manner include the shells, which are simply refuse, and the shell contents which make up the edible portion. The inside of the potato and the wheat flour are the edible portion, and the skin and bran are refuse of potatoes and wheat.

If we weigh the whole meat, bone and all, to start with, and afterwards weigh bone and other refuse and the meat, we can easily calculate the percentages of refuse and edible portion. If we then determine the percentages of water, water-free substance in the meat, as we can do by drying the water out and weighing the dried residue; and then burn the latter and weigh the ash which is left, we have made a fair start in the analysis for determining the value for nourishment.

Nutrients.—The water-free substance contains all of the nutritive materials, or nutrients, but the analysis thus far has told only the percentage of ash, or mineral matters. The proportions of the other ingredients must be found out before we can judge exactly of the food value.

Protein.—The meat consists of lean and fat. Part of the fat is in large lumps, which can be easily separated from the lean. Indeed, we often cut out the fat of the meat which is served on our plates at the table, and reject it instead of eating it. But a portion of the fat is in very fine particles diffused throughout the lean. Much of this finely divided fat is in particles so small as to be invisible to the naked eye, but it is possible to separate

them very completely from the lean by processes of analysis common in the laboratory. After the water and the fat have been removed from the lean meat the material which remains will contain a little mineral matter, which would be left as ash if it were burned; the rest consists chiefly of so-called protein compounds. The protein is the chief nutritive constituent of fish and eggs, as well as of lean meat. It occurs also in milk and in vegetable foods, such as wheat, corn, potatoes, etc.

Fat.—Fat is familiar to us in meat, from which we get it in the form of tallow and lard; in milk, from which it is obtained as butter; and in the various oils, such as olive oil, cotton-seed oil, and the oils of wheat and corn. Larger or smaller proportions of fat are found in most food materials.

Carbohydrates.—Potatoes, wheat, and corn contain large proportions of starch. Sugar cane and sorghum are rich in sugar. Starch and sugar are very similar in chemical composition, and are called carbohydrates. Other carbohydrates are found in animals and plants, such as glycogen or "animal starch," which is found in the liver, and cellulose, which occurs in plants.

Ash.—The mineral matter, or ash, which is left behind when animal or vegetable matter is burned, consists of a variety of chemical compounds commonly called salts, and including phosphates, sulphates, and chlorides of the metals calcium, magnesium, potassium, and sodium. Calcium phosphate, or phosphate of lime, is the chief mineral constituent of bone. Common salt is chloride of sodium.

For nourishment we need all of the different classes of nutrients and in proper proportions. Thus a day's food for an average man doing moderately hard muscular work may appropriately supply on the average, about $4\frac{1}{3}$ ounces of protein, the same quantity of fats, and 16 ounces of carbohydrates.

To recapitulate briefly: From the standpoint of their uses in the nutrition of man, the constituents of ordinary foods may be classified as follows:—

Edible substance, as the flesh of meats and fish, the shell contents of oysters, wheat flour.

Refuse, as bones of meat and fish, the shells of oysters, bran of wheat.

The edible substance consists of (1) water, (2) nutritive substance, or nutrients.

The water, refuse, and the salt of salted meat and fish are called non-nutrients. The water contained in foods and beverages has the same composition and properties as other water; it is, of course, indispensable for nourishment, but it is not a nutrient in the sense in which it is here used. In comparing the values of different food materials for nourishment, the refuse and water are left out of account.

Classes of Nutrients.

The following are familiar examples each of the four principal classes of nutrients:—

<i>Protein,</i> - -	{	Albuminoids: <i>e. g.</i> , albumen (white of eggs); casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.
		Gelatinoids: <i>e. g.</i> , collagen of tendons; ossein of bones, which yield gelatine or glue, etc.
		Meats and fish contain very small quantities of so-called "extractives." They include kreatin and allied compounds, and are the chief ingredients of beef-tea and meat extract. They contain nitrogen, and hence are commonly classed with protein.
<i>Fats,</i> - -	{	<i>e. g.</i> , fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.
<i>Carbohydrates,</i> -	{	<i>e. g.</i> , sugar, starch, cellulose (woody fiber), etc.
<i>Mineral Matters,</i>	{	<i>e. g.</i> , calcium phosphate or phosphate of lime, sodium chloride (common salt), etc.

HOW FOOD IS USED IN THE BODY.

The two chief uses of food of animals are: First, to form the material of the body and make up its wastes; and, second, to yield energy in the form of heat to keep the body warm and muscular and other power for the work it has to do. In forming the tissues and fluids of the body the food serves for building and repair. In yielding energy it serves as fuel.

The different nutrients of food act in different ways in fulfilling these purposes. The principal tissue formers are the protein compounds. These form the framework of the body. They build up and repair the nitrogenous materials, as the muscle and bone, and supply the albuminoids of blood, milk and other fluids. The chief fuel-ingredients of the food are the carbohydrates and fats. These are either consumed in the body, or are stored as fat to be used as occasion demands. In being used as fuel the nutrients of the food tend to protect each other and the materials of the body from being consumed.

The bodily machine is made of protein. That is to say, blood, muscle, tendon, bone, and brain, all consist of, or at least contain, protein compounds. These are formed from the myosin of meat and fish, the casein of milk, the albumen of eggs, the gluten of wheat and other compounds. As the muscle and other tissues are used up in bodily activity, the same materials of the food are used for their repair. Of course, the mineral matters have a good deal to do with the building up of the tissues. Thus, phosphate of lime is an essential ingredient of the bones.

But the machine needs fuel. The starch of the bread and the potatoes we eat and the sugar put in our coffee, are burned in the body and yield heat and power, just as truly as does the coal which is burned in a stove to heat the house; or under a boiler to drive an engine. The fats serve the same purpose, only they are a more concentrated fuel than the carbohydrates. The body transforms the carbohydrates into fat, which it keeps as a reserve of fuel in the most concentrated form.

But the protein compounds can also serve as fuel. A dog can live on lean meat. We can likewise use the protein of our bodies to supply us with heat and muscular strength. The animal machine differs from others in that it can use its own substance for fuel.

The different food ingredients can, to a greater or less extent, do one another's work. If the body has not enough of one for fuel it can use another. But while the protein can be consumed for fuel in the place of fats or carbohydrates, neither of the latter can take the place of protein in building and repairing the tissues of the body.

THE POTENTIAL ENERGY OF FOOD.

Heat and muscular power, like mechanical power, light, and electricity, are forms of energy. The energy is latent in the food, and is developed as the food is consumed in the body. We call it potential energy, and measure its quantity as we measure quantities of heat or of mechanical power. In other words, the value of food for fuel is expressed in terms of potential energy. The quantities of potential energy in food materials are determined by experiments with an apparatus called the calorimeter. The unit commonly used is the Calorie*, the amount of heat

* The same word calorie, but spelled with a small c, is used to designate the heat required to raise the temperature of a gram of water a degree. One Calorie is thus equal to 1,000 calories.

which would raise the temperature of a kilogram of water one degree centigrade (or a pound of water four degrees Fahrenheit). Instead of this unit of heat we may use a unit of mechanical energy, for instance the foot-ton, which is the force that would lift one ton one foot. One Calorie corresponds very nearly to 1.53 foot-tons.

Taking ordinary food materials as they come, the following general estimate has been made* for the average amount of energy in one gram of each of the classes of nutrients.

POTENTIAL ENERGY IN NUTRIENTS OF FOOD.

						CALORIES.	FOOT-TONS.
In one gram of protein,	-	-	-	-	-	4.1	6.3
In one gram of fats,	-	-	-	-	-	9.3	14.2
In one gram of carbohydrates,	-	-	-	-	-	4.1	6.3

These figures mean that when a gram of fat, be it the fat of food or body-fat, is consumed in the body, it will, if its potential energy be all transformed into heat, yield enough to warm nine and three-tenths kilograms of water one degree of the centigrade thermometer, (or four pounds of water one degree Fahrenheit), or, if it be transformed into mechanical energy, such as the steam-engine or the muscles use to do their work, it will furnish as much as would raise one ton fourteen and two-tenths feet, or fourteen and two-tenths tons one foot. A gram of protein or carbohydrates would yield a little less than half as much energy as a gram of fat.

It must be remembered that we are to-day only at the beginning of our knowledge of these subjects, and a very large amount of the most laborious, painstaking, and abstract inquiry will be needed to tell satisfactorily what needs to be known. But we are doubtless warranted in using these figures with the distinct understanding that they are subject to such revision as future research shall indicate.

In other words, when we compare the nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, an ounce of protein of lean meat or albumen of egg is just about equivalent to an ounce of sugar or starch; and a little over two ounces of either would be required to equal an ounce of the fat of meat or butter or the body-fat. The potential energy in the ounce of protein or carbohydrates would, if transformed into

* By Prof. Rubner. *Zeitschrift für Biologie*, 19, 313. These estimates are tentative. Doubtless future research will alter them more or less.

heat, suffice to raise the temperature of one hundred and thirteen pounds of water one degree Fahrenheit, while an ounce of fat, if completely burned in the body or in the calorimeter, would yield as much heat as would warm over twice that weight of water one degree.

What has been said above about the ways in which our food nourishes us may be briefly summarized as follows:

WAYS IN WHICH FOOD IS USED IN THE BODY.

Food supplies the wants of the body in several ways. It either:

1. Is used to form the tissues and fluids of the body;
2. Is used to repair the wastes of tissues;
3. Is stored in the body for future consumption;
4. Is consumed as fuel, its potential energy being transformed into heat or muscular energy or other forms of energy required by the body; or,
5. In being consumed protects tissues or other food from consumption.

Uses of the Different Classes of Nutrients.

Protein forms tissue (muscle, tendon, etc., and fat) and serves as fuel.	} All yield energy in form of heat and muscular strength.
Fats form fatty tissue (not muscle, etc.,) and serve as fuel.	
Carbohydrates are transformed into fat and serve as fuel.	

In being themselves burned to yield energy, the nutrients protect each other from being consumed. The protein and fats of body-tissue are used like those of food. An important use of the carbohydrates and fats is to protect protein (muscle, etc.), from consumption.

Table 60, showing the composition of specimens of some of our more common animal and vegetable foods, follows on pages 170, 171. The last column gives the number of Calories in one pound of each food material. These are estimated from the proportions of nutrients as indicated in the table.*

The first part of the table gives the chemical composition, including both edible portion and refuse. It is interesting to note the difference in the amounts of refuse and edible portion in the different kinds of meats, fish, etc., as they are ordinarily found in

*The figures for potential energy are calculated for each food material by multiplying the number of grams of protein and of carbohydrates in one pound (1 lb. equals 453.6 grams) by 4.1, and the number of grams of fat by 9.3, and taking the sum of these three products as the number of Calories of potential energy in a pound of the material.

TABLE 60.

Percentages of Nutrients (Nutritive Ingredients), Water, and Refuse, and Estimated Potential Energy (Fuel Value) in Specimens of Food Materials.

FOOD MATERIALS.	Refuse (Bones, Skin, Shell, etc.)	EDIBLE PORTION.							Potential En- ergy in one Pound.
		Water.	NUTRIENTS.					Potential En- ergy in one Pound.	
			Total.	Protein.	Fat.	Carbo- hydrates.	Mineral Matters.		
<i>Animal Foods, as Purchased.</i>	%	%	%	%	%	%	%	Cal.	
<i>Beef</i> —Neck, - - - -	20.0	49.6	30.4	15.6	14.0	—	0.8	880	
Shoulder, - - - -	12.6	55.8	31.6	17.0	13.7	—	0.9	895	
Chuck rib, - - - -	14.6	49.5	35.9	15.0	20.1	—	0.8	1125	
Rib, - - - -	21.0	38.2	40.8	12.2	27.9	—	0.7	1405	
Sirloin, - - - -	19.5	48.3	32.2	15.0	16.4	—	0.8	970	
Round steak, - - -	7.8	60.9	31.3	18.0	12.3	—	1.0	855	
Side, without kidney fat,	19.2	44.3	36.5	13.9	21.8	—	0.8	1180	
Rump, corned, - - -	5.0	70.8	24.2	16.7	5.1	—	2.4	525	
Flank, corned, - - -	12.1	43.7	44.2	12.4	29.2	—	2.6	1460	
<i>Veal</i> —Shoulder, - - -	17.9	56.7	25.4	16.6	7.9	—	0.9	640	
<i>Mutton</i> —Shoulder, - -	16.3	49.0	34.7	15.1	18.8	—	0.8	1075	
Leg, - - - -	18.1	50.6	31.3	15.0	15.6	—	0.7	935	
Loin, - - - -	15.8	41.5	42.7	12.6	29.5	—	0.6	1480	
Side, without kidney fat,	17.3	44.2	38.5	14.0	23.7	—	0.8	1260	
<i>Pork</i> —Shoulder roast, fresh, -	14.6	43.0	42.4	13.6	28.0	—	0.8	1435	
Ham, salted, smoked, -	11.4	36.8	51.8	14.8	34.6	—	2.4	1735	
<i>Chicken</i> , - - - -	38.2	44.6	17.2	15.1	1.2	—	0.9	330	
<i>Turkey</i> , - - - -	32.4	44.7	22.9	16.1	5.9	—	0.9	550	
<i>Eggs</i> , in shell, - - -	13.7	63.1	23.2	12.1	10.2	—	0.9	655	
<i>Fish, etc.</i> —Flounder, whole, -	66.8	27.2	6.0	5.2	0.3	—	0.5	110	
Bluefish, dressed, - -	48.6	43.0	11.1	9.8	0.6	—	0.7	210	
Codfish, dressed, - -	29.9	58.5	11.6	10.6	0.2	—	0.8	205	
Shad, whole, - - -	50.1	35.2	14.7	9.2	4.8	—	0.7	375	
Mackerel, whole, - -	44.8	40.4	15.0	10.0	4.3	—	0.7	365	
Halibut, dressed, - -	17.7	61.9	20.4	15.1	4.4	—	0.9	465	
Salmon, whole, - - -	35.3	40.6	24.1	14.3	8.8	—	1.0	635	
Salt codfish, - - -	42.1	40.5	17.6	16.0	0.4	—	1.2	315	
Smoked herring, - - -	50.9	19.2	29.9	20.2	8.8	—	0.9	745	
Salt mackerel, - - -	40.4	28.1	31.5	14.7	15.1	—	1.7	910	
Canned salmon, - - -	4.9	59.3	35.8	19.3	15.3	—	1.2	1005	
Lobsters, - - - -	62.1	31.0	6.9	5.5	0.7	0.1	0.6	135	
Oysters, - - - -	82.3	15.4	2.3	1.1	0.2	0.6	0.4	40	
<i>Animal Foods, Edible Portion.</i>									
<i>Beef</i> —Neck, - - - -	—	62.0	38.0	19.5	17.5	—	1.0	1100	
Shoulder, - - - -	—	63.9	36.1	19.5	15.6	—	1.0	1020	
Chuck rib, - - - -	—	58.0	42.0	17.6	23.5	—	0.9	1320	
Rib, - - - -	—	48.1	51.9	15.4	35.6	—	0.9	1790	
Sirloin, - - - -	—	60.0	40.0	18.5	20.5	—	1.0	1210	
Round, - - - -	—	68.2	31.8	20.5	10.1	—	1.2	805	
Side, without kidney fat,	—	54.8	45.2	17.2	27.1	—	0.9	1465	
Rump, corned, - - -	—	58.1	41.9	13.3	26.6	—	2.0	1370	
Flank, corned, - - -	—	49.8	50.2	14.2	33.0	—	3.0	1655	
<i>Veal</i> —Shoulder, - - -	—	68.8	31.2	20.2	9.8	—	1.2	790	
<i>Mutton</i> —Shoulder, - - -	—	58.6	41.4	18.1	22.4	—	0.9	1280	
Leg, - - - -	—	61.8	38.2	18.3	19.0	—	0.9	1140	
Loin, - - - -	—	49.3	50.7	15.0	35.0	—	0.7	1755	

TABLE 60.—(Continued.)

FOOD MATERIALS.	Refuse (Bones, Skin, Shell, etc.)	EDIBLE PORTION.						Pot'nl En'gy in one Pound.
		Water.	NUTRIENTS.					
			Total.	Protein.	Fat.	Carbo- hydrates.	Mineral Matters.	
<i>Animal Foods, Edible Portion.</i>	%	%	%	%	%	%	%	Cal.
<i>Mutton</i> —Side, without kidney fat	—	53.5	46.5	16.9	28.7	—	0.9	1525
<i>Pork</i> —Shoulder roast, fresh, -	—	50.3	49.7	16.0	32.8	—	0.9	1680
Ham, salted, smoked, -	—	41.5	58.5	16.7	39.1	—	2.7	1960
Fat, salted, -	—	12.1	87.9	0.9	82.8	—	4.2	3510
<i>Sausage</i> —Pork, -	—	41.2	58.8	13.8	42.8	—	2.2	2065
Bologna, -	—	62.4	37.6	18.8	15.8	—	3.0	1015
<i>Chicken</i> , -	—	72.2	27.8	24.4	2.0	—	1.4	540
<i>Turkey</i> , -	—	66.2	33.8	23.9	8.7	—	1.2	810
<i>Eggs</i> , -	—	73.8	26.2	14.9	10.5	—	0.8	721
<i>Milk</i> , -	—	87.0	13.0	3.6	4.0	4.7	0.7	325
<i>Butter</i> , -	—	10.5	89.0	1.0	85.0	0.5	3.0	3615
<i>Oleomargarine</i> , -	—	11.0	89.5	0.6	85.0	0.4	3.0	3605
<i>Cheese</i> —Full cream, -	—	30.2	69.8	28.3	35.5	1.8	4.2	2070
Skim-milk, -	—	41.3	58.7	38.4	6.8	8.9	4.6	1165
<i>Fish</i> —Flounder, -	—	84.2	15.8	13.8	0.7	—	1.3	285
Haddock, -	—	81.7	18.3	16.8	0.3	—	1.2	325
Codfish, -	—	82.6	17.4	15.8	0.4	—	1.2	310
Shad, -	—	70.6	29.4	18.6	9.5	—	1.3	745
Mackerel, -	—	73.4	26.6	18.2	7.1	—	1.3	640
Halibut, -	—	75.4	24.6	18.3	5.2	—	1.1	560
Salmon, -	—	63.6	36.4	21.6	13.4	—	1.4	965
Salt cod, -	—	53.6	—	21.4	0.3	—	1.6	410
Herring, salt, -	—	34.6	—	36.4	15.8	—	1.5	1345
Mackerel, salt, -	—	43.4	—	17.3	26.4	—	2.6	1860
Oysters, -	—	87.1	12.9	6.0	1.2	3.7	2.0	230
<i>Vegetable Foods.</i>								
Wheat flour, -	—	12.5	87.5	11.0	1.1	74.9	0.5	1644
Graham flour (wheat), -	—	13.1	86.9	11.7	1.7	71.7	1.8	1625
Rye flour, -	—	13.1	86.9	6.7	0.8	78.7	0.7	1625
Buckwheat flour, -	—	14.6	85.4	6.9	1.4	76.1	1.0	1605
Oatmeal, -	—	7.6	92.4	15.1	7.1	68.2	2.0	1850
Cornmeal, -	—	15.0	85.0	9.2	3.8	70.6	1.4	1645
Rice, -	—	12.4	87.6	7.4	0.4	79.4	0.4	1630
Peas, -	—	12.3	87.7	26.7	1.7	56.4	2.9	1565
Beans, -	—	12.6	87.4	23.1	2.0	59.2	3.1	1615
Potatoes, -	—	78.9	21.1	2.1	0.1	17.9	1.0	375
Sweet potatoes, -	—	71.1	28.9	1.5	0.4	26.0	1.0	530
Turnips, -	—	89.4	10.6	1.2	0.2	8.2	1.0	185
Carrots, -	—	88.6	11.4	1.1	0.4	8.9	1.0	200
Onions, -	—	87.6	12.4	1.4	0.3	10.1	0.6	225
String beans, -	—	87.2	12.8	2.2	0.4	9.4	0.8	235
Green peas, -	—	78.1	21.9	4.4	0.6	16.0	0.9	405
Green corn, -	—	81.3	18.7	2.8	1.1	13.2	0.6	345
Tomatoes, -	—	96.0	4.0	0.8	0.4	2.5	0.3	80
Cabbage, -	—	91.9	8.1	2.1	0.3	5.5	1.1	155
Apples, -	—	83.2	16.8	0.2	0.4	15.9	0.3	315
Sugar, granulated, -	—	2.0	98.0	—	—	97.8	0.2	1820
Molasses, -	—	24.6	75.4	—	—	73.1	2.3	1360
White bread (wheat), -	—	32.3	67.7	8.8	1.7	56.3	0.9	1280
Boston crackers, -	—	8.3	91.7	10.7	0.9	68.7	2.4	1895

the markets. In some specimens of meats, as round steak, the bone and other inedible portions are less than one-tenth of the whole, whereas in the flounder the refuse amounts to two-thirds and the edible portion to only one-third of the whole.

In the part of the table which gives the percentages of nutrients in the edible portion of foods, it is interesting to note the wide variations in the proportions of water and of nutrients. In general, the animal substances contain the most water and the vegetable foods the most nutrients, though potatoes and turnips and allied green vegetables are exceptions. Meats have more water in proportion as they have less fats. Thus, very lean beef is nearly three-fourths water, while other and fatter cuts are less than one-half water. The flesh of fish is in general more watery than that of ordinary meats. Flour and meal have very little water, and sugar almost none. In examining the proportions of individual nutrients, the most striking fact is the difference between the meats and the fish, on one hand, and the vegetable foods on the other hand. The vegetable foods are rich in carbohydrates, and the meats abound in protein and fats, of which the vegetable foods usually have but little. Beans and oatmeal, however, are rich in protein, while fat pork has very little.

It must be borne in mind, however, that different specimens of the same kind of material may differ widely in composition, especially in the case of meats, and that the figures here given are based upon the comparatively few analyses now available. Many more analyses will be needed to show the ranges of variation and the actual averages.

ACTUAL DIETARIES OF DIFFERENT CLASSES OF PEOPLE.

Table 61* gives the quantities of nutrients and potential energy in a number of observed dietaries. The figures for European dietaries are mostly by Voit and his followers in Germany, and by Playfair in England. The American figures are by the writer and his associates; those for the army and navy rations are based upon the United States Regulations, the rest upon observations of actual dietaries.

As the subject was discussed at some length in the Report of the Station for 1891 (pp. 106-159), and it is the purpose to recur to it later, the citing of the figures will suffice here. The dietary standards indicate the amounts assumed to be appropriate for nourishment on the average, and are subject to revision.

* Quoted from Experiment Station Record, Vol. III., p. 673.

American and European Dietsaries and Dietary Standards.

TABLE 61.

[Quantities per man per day.]

DIETARIES.	Nutrients.			Potential Energy.	Nutritive Ratio.
	Protein.	Fats.	Carbohydrates.		
	gm.	gm.	gm.	Cal.	1:
<i>American (Massachusetts and Connecticut.)</i>					
Family of glass blowers in East Cambridge, Mass., -	95	132	481	3,590	8.2
Boarding house, Lowell, Mass.; boarders, operatives in cotton mills, -	132	200	549	4,650	7.6
Boarding house, Middletown, Conn.; { Food purchased	126	188	426	4,010	6.8
well-paid machinists, etc., at moderate work, -	103	152	402	3,490	7.3
Blacksmiths, Lowell, at hard work, -	200	304	795	6,905	7.4
Brickmakers, Mass.; 237 persons at very severe work, -	180	365	1,150	8,850	11.0
Mechanics, etc., in Massachusetts and Connecticut; average of 4 dietsaries of mechanics at severe work (not including No. 5), -	215	296	749	6,705	6.6
Average of 20 dietsaries of wage-workers in Massachusetts and Connecticut, -	152	225	625	5,275	7.5
Average of 5 dietsaries of professional men and college students in Middletown, Conn., -	133	163	508	4,140	6.6
{ Food eaten, -	126	152	489	3,925	6.6
<i>European (English, German, Danish, and Swedish.)</i>					
Well-fed tailors, England, Playfair, -	131	39	525	3,055	4.7
Hard-worked weavers, England, Playfair, -	151	43	622	3,570	4.8
Blacksmiths at active labor, England, Playfair, -	176	71	667	4,115	4.7
Mechanic, Munich, 60 years old, in comfortable circumstances, light work, Forster, -	117	68	345	2,525	4.3
Well-paid mechanics, Munich, Voit, -	151	54	479	3,085	4.0
Carpenters, coopers, locksmiths, Bavaria; average of 11 dietsaries, -	122	34	570	3,150	5.3
Miners at severe work, Prussia, Steinheil, -	133	113	634	4,195	6.7
Brickmakers (Italians), Munich, diet mainly maize meal and cheese, severe work, -	167	117	675	4,540	5.6
German army ration, peace footing, -	114	39	480	2,800	5.0
German army ordinary ration, war footing, -	134	58	489	3,095	4.6
German army extraordinary ration, in war, -	192	45	678	3,985	4.1
University professor, Munich; very little exercise, Lawyer, Munich, Forster, -	100	100	240	2,325	4.7
-	80	125	222	2,400	6.3
Physician, Munich, Forster, -	127	89	362	2,830	4.4
Physician, Copenhagen, Jürgeson, -	135	140	239	2,835	4.1
Average of 7 dietsaries of professional men and students, -	114	111	285	2,670	4.7
<i>Dietary Standards.</i>					
Adult in full health, Playfair, -	119	51	531	3,140	5.5
Active laborers, Playfair, -	156	71	568	3,630	4.7
Man at moderate work, Moleschott, -	130	40	550	3,160	4.9
Man at moderate work, Wolff, -	125	35	540	3,030	4.9
Man at moderate work, Voit, -	118	56	500	3,055	5.3
Man at hard work, Voit, -	145	100	450	3,370	4.7
Man with moderate muscular work, writer, -	125	125	450	3,520	5.9
Man with active muscular work, writer, -	150	150	500	4,060	5.6
Man at severe muscular work, writer, -	175	250	650	5,705	6.9
Man at very severe muscular work, writer, -	200	350	800	7,355	7.9

THE DIGESTIBILITY OF FOOD.

"We live upon not what we eat, but what we digest." In other words, the value of food for nutriment depends not only on how much of nutrients it contains, but also upon how much of these the body digests and uses for its support.

By digestibility of food several different things are, or may be, meant. Some of these, as the ease with which a given food-material is digested, the time required for the process, the influence of different substances and conditions on digestion, and the effects upon health and comfort are so dependent upon the peculiarities of different individuals, and are so difficult of measurement as to make the laying down of hard-and-fast rules impossible. For our present purpose, the most important factor is the amount digested. This, fortunately, is more easy to determine. Understanding by the digestibility of a food the proportions of each of the nutrients which can be actually digested by healthy persons, the question becomes simpler and can be answered more or less accurately by experiment.

One outcome of the careful experimenting of the last few years is the proof that there is not the difference in the amounts digested from the same kind of food material by different persons or by the same person under different circumstances, that has been popularly supposed.

The percentages of the more important constituents of various foods actually digested by domestic animals of different kinds, horses, oxen, cows, sheep, swine, etc., have been a matter of active experimental investigation in the experiment stations in Europe for the last thirty years. Of late a number of American stations have been engaged in similar inquiries. Briefly expressed, the method consists in weighing and analyzing both the food consumed and the solid excrement. Since the latter represents the amount of food undigested and unassimilated, the difference is taken as the amount digested.

Such experiments are more difficult with human subjects than with domestic animals, because men are accustomed to more varied diet. To make an experiment on the digestibility of a given food most accurate it should be eaten by itself. An ox will thrive comfortably for a long time on a single kind of fodder, as hay, but most men are used to a mixed diet, and it is not easy to continue to eat the same kind of food long enough for a satis-

factory trial; and there is, furthermore, the danger that the accuracy of the experiment may be impaired through derangement of the digestive organs by the long restriction to one kind of food. The number of experiments upon the digestibility of food of man is small. Scarcely more than a hundred reliable series have been reported. The very large majority of them have been made in Germany, most of them with healthy men. In table 62 herewith, which, like the others in this article, has been prepared with the aid of Mr. C. D. Woods, the attempt is made to epitomize the results of the majority of these experiments. The figures for the animal foods are probably not far from correct. Of the figures for the vegetable foods, those for the protein are nearly accurate, the percentage assumed for the carbohydrates is doubtless not far out of the way, that for the fats is the least reliable. The numbers in the table which thus represent the proportions of the several kinds of nutrients that are actually digested are called co-efficients of digestibility.

TABLE 62.

Digestibility of Nutrients of Food Materials.

ANIMAL FOODS.	PERCENTAGES DIGESTED.			VEGETABLE FOODS.	PERCENTAGES DIGESTED.		
	Protein.	Fat.	Carbo-hydrates.		Protein.	Fat.	Carbo-hydrates.
	%	%	%		%	%	%
Beef and veal, - -	100	95	—	Wheat flour, fine, -	85	80 % assumed for all.	95 % assumed for all.
Mutton, - - -	100	95	—	Wheat flour, medium, -	81		
Pork, - - -	100	95	—	Wheat flour, coarse, -	75		
Fish and oysters, -	100	95	—	Rice, - - -	85		
Milk, - - -	100	96	100	Macaroni, - - -	85		
Cheese, - - -	100	95	100	Rye flour, - - -	78		
Butter, - - -	—	96	—	Maize meal, - - -	85		
Oleomargarine, -	—	95	—	Potatoes, - - -	75		
Tallow, - - -	—	95	—	Cabbages, turnips, etc.,	80	80 % assumed for all.	95 % assumed for all.
Lard, - - -	—	95	—	Beans, - - -	85		
Oils, - - -	—	95	—	Peas, - - -	85		
Eggs, - - -	100	98	—				

Table 63 exhibits, for a number of food materials, the proportions of nutrients which are estimated to be digestible. It was computed by applying the figures in table 62 to the figures for composition of food materials in table 60 above. Thus, in beef

the whole of the protein (100 per cent. in table 62) is assumed to be digestible. The average of the analyses of shoulder of beef, epitomized in table 60, gives 19.5 per cent. of protein. This is, accordingly, the percentage assumed to be digestible. In wheat flour 85 per cent. of the total protein is estimated to be digestible, the remainder, 15 per cent., being undigestible. The wheat flour of table 60 contains 11 per cent. of protein. Accordingly 9.4 per cent. will be digestible and 1.6 per cent. undigestible.

TABLE 63.

Estimates of Proportions of Digestible and Undigestible Nutrients in Food Materials.

FOOD MATERIALS.	PROTEIN.			FATS.			CARBO- HYDRATES.		
	Digested.	Undigested.	Total.	Digested.	Undigested.	Total.	Digested.	Undigested.	Total.
	%	%	%	%	%	%	%	%	%
Beef, shoulder, - - -	19.5	—	19.5	14.8	.8	15.6	—	—	—
Beef, sirloin, - - -	18.5	—	18.5	19.5	1.0	20.5	—	—	—
Beef, round, - - -	20.5	—	20.5	9.6	.5	10.1	—	—	—
Veal, shoulder, - - -	20.2	—	20.2	9.3	.5	9.8	—	—	—
Mutton, shoulder, - - -	18.1	—	18.1	21.3	1.1	22.4	—	—	—
Mutton, loin, - - -	15.0	—	15.0	33.3	1.7	35.0	—	—	—
Pork, shoulder, - - -	16.0	—	16.0	31.2	1.6	32.8	—	—	—
Pork, very fat, - - -	.9	—	.9	78.7	4.1	82.8	—	—	—
Eggs, - - -	14.9	—	14.9	10.3	.2	10.5	—	—	—
Milk, - - -	3.6	—	3.6	3.8	.2	4.0	4.7	—	4.7
Butter, - - -	?	?	1.0	81.6	3.4	85.0	.5	—	.5
Cheese, full cream, - - -	28.3	—	28.3	33.7	1.8	35.5	1.8	—	1.8
Cheese, skim milk, - - -	38.4	—	38.4	6.5	.3	6.8	8.9	—	8.9
Haddock, - - -	16.8	—	16.8	.3	—	.3	—	—	—
Bluefish, - - -	19.0	—	19.0	1.1	.1	1.2	—	—	—
Cod, - - -	15.8	—	15.8	.4	—	.4	—	—	—
Shad, - - -	18.6	—	18.6	9.0	.5	9.5	—	—	—
Mackerel, - - -	18.8	—	18.8	7.8	.4	8.2	—	—	—
Halibut, - - -	18.3	—	18.3	4.9	.3	5.2	—	—	—
Salmon, - - -	21.6	—	21.6	12.7	.7	13.4	—	—	—
Wheat flour, fine, - - -	9.4	1.6	11.0	.9	.2	1.1	71.1	3.8	74.9
Wheat flour, medium, - - -	9.5	2.2	11.7	1.4	.3	1.7	68.1	3.6	71.7
Cracked wheat, - - -	8.9	3.0	11.9	1.4	.3	1.7	70.9	3.7	74.6
Maize meal, - - -	7.8	1.4	9.2	3.0	.8	3.8	67.1	3.5	70.6
Rice, - - -	6.3	1.1	7.4	.3	.1	.4	75.4	4.0	79.4
Potatoes, - - -	1.6	.5	2.1	?	?	0.1	17.0	.9	17.9
Turnips, - - -	1.0	.2	1.2	?	?	0.2	7.8	.4	8.2
Beets, - - -	1.2	.3	1.5	?	?	0.1	8.5	.4	8.9
Wheat bread, - - -	7.1	1.7	8.8	1.4	.3	1.7	53.4	2.8	56.2
Rye bread, - - -	6.5	1.9	8.4	.4	.1	0.5	56.7	3.0	59.7
Graham bread, - - -	7.1	2.4	9.5	1.1	.3	1.4	50.6	2.7	53.3

The results of experimental inquiry regarding the quantities of nutrients digested from reasonable amounts of ordinary food materials by healthy people may be briefly summarized as follows:

1. The protein of our ordinary meats, fish, and milk is very readily and completely digested. The protein of vegetable foods is much less completely digested than that of animal foods. Of that of potatoes and beans, for instance, a third or more may escape digestion, and thus be useless for nourishment.

2. Much of the fats of animal food may at times fail of digestion. This is presumably true of vegetable fats, but the quantities are in general so small that the determinations of the proportions digested are not very accurate.

3. The carbohydrates, which make up a large part of vegetable food, are in general very digestible. The crude fiber or cellulose is an exception, but the quantities of this in the materials used for the food of man are too small to be of importance. Sugar is believed to be completely digested. This is assumed to be the case with the sugar of milk. The other carbohydrates of animal foods are very small in amount.

4. The animal foods have in general the advantage of the vegetable foods in digestibility, that they contain more protein and that their protein is more digestible.

5. The quantity digested appears to be less affected by flavor, flavoring materials and food adjuncts and to differ less with different persons, than is commonly supposed.

PECUNIARY ECONOMY OF FOOD.

The cost of food is the principal item of the living expenses of the majority of people, of all, indeed, but the especially well-to-do in Connecticut and the other Eastern States.* In the Report of the Bureau of Statistics of Labor of Massachusetts for 1884 are summarized the results of investigations into the cost of living of people with different incomes in Massachusetts, in Great Britain, and in Germany. Dividing expenses into those for food, clothing, rent, fuel, and sundries, the percentage of the whole income expended for food averages as follows:

*In portions of the West and South, where food is less expensive, its cost is somewhat less in comparison with other living expenses.

Percentage of Family Income Expended for Subsistence.

	ANNUAL INCOME.	PER CENT. EXPENDED FOR FOOD.
<i>Germany.</i>		
Workingmen, - - - - -	\$225 to \$300	62
Intermediate class, - - - - -	450 to 600	55
In easy circumstances, - - - - -	750 to 1100	50
<i>Great Britain.</i>		
Workingmen, - - - - -	\$500	51
<i>Massachusetts.</i>		
Workingmen, - - - - -	\$350 to \$400	64
Workingmen, - - - - -	450 to 600	63
Workingmen, - - - - -	600 to 750	60
Workingmen, - - - - -	750 to 1200	56
Workingmen, - - - - -	Above 1200	51

The large majority of families in this country are said to have not over \$500 a year to live upon. More than half of this goes, and must go, for food. The cost of preparing food for the table, rent, clothing, and all other expenses must be provided from the remainder.

These statements apply less accurately to farmers than to the inhabitants of the larger towns, but, although the farmer produces much of his food, yet taking everything into account the expense for nutriment is large even for him.

Although the cost of food makes so large a part of the whole cost of living, and although the health and strength of all are so intimately connected with and dependent upon their diet, yet even the most intelligent people know less of the actual uses and values of their food for fulfilling its purposes than of almost any other of the necessities of life.

Cheap vs. Dear Food.—The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time best adapted to the wants of the user. The maxim that "the best is the cheapest" does not apply to food. The best food in the sense of that which is the finest in appearance and flavor, and which is sold at the highest price, is not generally the cheapest, nor is it always the most healthful or economical.

There seems to be among the people of this country an idea that there is some mysterious virtue in those kinds of foods that have the most delicate appearance and flavor, and which command the highest price. The notion is current that whatever else one has or does not have, he must, if possible, have this sort of food, and that to economize by using anything inferior in quality or cheaper in price would be a sacrifice of both dignity and principle.

Mr. Lee Meriwether, who has given much attention to this especial subject, cites a case in point, that of a coal laborer who boasted: "No one can say that I do not give my family the best of flour, the finest of sugar, the very best quality of meat." He paid \$156 a year for the nicest cuts of meat, which his wife had to cook before six in the morning or after half past six at night, because she worked all day in a factory. When excellent butter was selling at 25 cents a pound he paid 29 cents for an extra quality. He spent only \$108 a year for clothing for his family of nine, and only \$72 a year for rent in a close tenement house, where they slept in rooms without windows or closets. He indulged in this extravagance in food when much less expensive food materials, such as regularly come upon the tables of men of wealth, would have been just as nutritious, just as wholesome, and in every way just as good, save in its gratification to pride and palate. He was committing an immense economic blunder. Like thousands of others, he did so without understanding at all that it was a blunder.

Just here is one great difficulty: the lack of information regarding the nutritive values of foods. Even those who wish and try to economize in their purchase and use of food do not understand how. They carefully consult the prices, but have in general very vague ideas about values for nourishment as compared with cost. Persons who are exceedingly economical in purchase of clothing, and in other expenditures, do not, and in many instances cannot practice intelligently the same economy at the markets. Frequently people pay from one to two dollars a pound for the protein of the meat and other animal foods they use, when it might be obtained in forms equally wholesome and nutritious for 15 to 50 cents per pound. The food thus purchased is apt to supply some of the nutrients in excessive amounts as well as at needlessly high costs, while it furnishes others in insufficient quantities or in unfitting forms and in uneconomical ways, and only too often a large part of it finds its way into the drain or the garbage barrel instead

of being utilized for nourishment. The difficulty is that in comparing different food materials with respect to their cheapness or dearness, we are apt to judge them by the prices per pound, quart or bushel, without much regard to the amounts or kinds of actual nutrients which they contain.

Of the different food materials which the market affords, and which are palatable, nutritious, and otherwise fit for nourishment, what ones are peculiarly the most economical? There are various ways of comparing food materials with respect to the relative cheapness or dearness of their nutritive ingredients. One, and perhaps the best, consists in comparing the nutrients obtained for a given sum in different materials. Table 64, which follows, gives estimates of amounts of nutrients that could be purchased for twenty-five cents at the rates named. The calculations are based upon the analyses in table 60, and upon the retail prices current in Connecticut.

The figures of the table tell their story so plainly that they need very little comment. A quarter of a dollar invested in the sirloin of beef at 22 cents per pound pays for one and one-seventh pounds of the meat with three-eighths of a pound of actually nutritive material. This would contain one-sixth of a pound of protein and one-fifth of a pound of fat, and supply 1,120 Calories of energy. The same amount of money paid for oysters at the rate of 50 cents per quart, brings two ounces of actual nutrients, an ounce of protein and 230 Calories of energy. But in buying wheat flour at seven dollars a barrel, the 25 cents pay for six and a quarter pounds of nutrients with eight-tenths of a pound of protein and 11,755 Calories of energy.

The price of food is not regulated solely by its value for nutriment. Its agreeableness to the palate or to the buyer's fancy makes a large factor of the current demand and market price. There is no more nutriment in an ounce of protein or fat of the tenderloin of beef than in that of the round or shoulder. The protein of animal foods does, however, have an advantage over that of vegetable foods. Animal foods, such as meats, fish, milk and the like, gratify the palate in ways which most vegetable foods do not, and, what is perhaps of still greater weight in regulating the actual usage of communities by whose demand the prices are regulated, they satisfy a real need by supplying protein and fats, which vegetable foods lack.

TABLE 64.

Amounts of Nutrients furnished for Twenty-five Cents in Food Materials at Ordinary Prices.

FOOD MATERIALS AS FURNISHED.	Prices per Pound.	TWENTY-FIVE CENTS WILL PAY FOR					
		Total Food Materials.	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo- hydrates.	
<i>Meats, Etc.</i>	Cts.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
<i>Beef, neck, - - - -</i>	8	3.13	.95	.49	.44	—	2765
	6	4.17	1.27	.65	.58	—	3655
<i>Chuck ribs, - - - -</i>	16	1.56	.56	.23	.31	—	1735
	12	2.08	.75	.31	.42	—	2350
<i>Ribs, - - - -</i>	22	1.14	.47	.14	.32	—	1610
	18	1.39	.57	.17	.39	—	1960
<i>Shoulder, - - - -</i>	14	1.79	.57	.30	.25	—	1615
	10	2.50	.79	.43	.34	—	2235
<i>Sirloin, - - - -</i>	22	1.14	.37	.17	.19	—	1120
	18	1.39	.45	.21	.23	—	1360
<i>Rump, - - - -</i>	18	1.39	.63	.19	.43	—	2170
	15	1.67	.76	.23	.52	—	2620
<i>Round, first cut, - - -</i>	18	1.39	.44	.25	.17	—	1180
	15	1.67	.52	.30	.21	—	1445
<i>Round, second cut, - -</i>	10	2.50	.52	.35	.15	—	1285
	8	3.13	.65	.44	.18	—	1580
<i>Flank, corned, - - - -</i>	15	1.67	.77	.21	.49	—	2460
	10	2.50	1.11	.31	.73	—	3655
<i>Corned and canned, - -</i>	18	1.39	.66	.37	.24	—	1700
	14	1.79	.85	.48	.31	—	2200
<i>Liver, - - - -</i>	8	3.13	.96	.63	.17	.11	2095
<i>Mutton, shoulder, - - -</i>	20	1.25	.41	.18	.22	—	1265
	15	1.67	.58	.25	.31	—	1775
<i>Leg, - - - -</i>	25	1.00	.31	.15	.16	—	955
	20	1.25	.39	.19	.20	—	1195
<i>Loin, - - - -</i>	25	1.00	.43	.13	.29	—	1465
	20	1.25	.53	.15	.37	—	1840
<i>Pork, rib roast, - - -</i>	12	2.08	.88	.28	.58	—	2970
	16	2.50	1.06	.34	.70	—	5885
<i>Smoked ham, whole, - -</i>	16	1.56	.86	.25	.58	—	2915
	12	2.08	1.08	.31	.72	—	3615
<i>Salt, fat pork, - - - -</i>	15	1.67	1.17	.02	1.38	—	5860
	12	2.08	1.03	.02	1.72	—	7295
<i>Pork sausage, - - - -</i>	15	1.67	.98	.23	.72	—	3465
	12	2.08	1.22	.29	.89	—	4295
<i>Poultry, etc., chicken, -</i>	22	1.14	.32	.28	.02	—	605
	16	1.56	.45	.38	.03	—	835
<i>Turkey, - - - -</i>	23	1.09	.37	.26	.09	—	865
	18	1.38	.47	.32	.12	—	1100

TABLE 64.—(Continued.)

FOOD MATERIALS AS FURNISHED.	Prices per Pound.	TWENTY-FIVE CENTS WILL PAY FOR					
		Total Food Materials,	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo- hydrates.	
<i>Fish, Etc.</i>	Cents.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
Shad, whole, - - - -	{ 15	1.67	.25	.15	.09	—	660
	{ 10	2.50	.37	.23	.12	—	935
	{ 18	1.39	.22	.14	.06	—	513
Mackerel, whole, - - -	{ 15	1.67	.25	.17	.07	—	610
	{ 10	2.50	.37	.25	.11	—	930
	{ 15	1.67	.19	.16	.01	—	340
Blue fish, dressed, - - -	{ 10	2.50	.28	.25	.02	—	550
	{ 18	1.39	.14	.12	.01	—	265
Striped bass, whole, - - -	{ 12	2.08	.21	.17	.02	—	400
	{ 8	3.13	.28	.26	.01	—	525
Haddock, dressed, - - -	{ 5	5.00	.45	.41	.01	—	805
	{ 10	2.50	.28	.25	.01	—	505
	{ 8	3.13	.36	.33	.01	—	655
Cod, dressed, - - - -	{ 6	4.17	.48	.44	.01	—	860
	{ 20	1.25	.26	.19	.06	—	605
Halibut, steaks, - - - -	{ 16	1.56	.32	.24	.07	—	740
	{ 8	3.13	.55	.50	.01	—	970
Salt cod, - - - -	{ 5	5.00	.88	.80	.02	—	1570
	{ 16	1.56	.49	.23	.24	—	1440
Salt mackerel, - - - -	{ 12	2.08	.66	.31	.32	—	1925
Canned salmon, - - - -	20	1.25	.46	.25	.20	—	1310
Oysters, 50c. per quart, - - -	25	1.00	.13	.06	.01	.04	230
Oysters, 35c. per quart, - - -	17.5	1.43	.18	.09	.02	.05	345
Lobster, whole, - - - -	{ 12	2.08	.14	.11	.01	—	345
	{ 10	2.50	.17	.14	.02	—	345
Lobster, canned, - - - -	20	1.25	.28	.23	.01	—	470
<i>Eggs and Dairy Products.</i>							
Eggs, 35c. per dozen, - - -	25	1.00	.23	.12	.10	—	645
Eggs, 25c. per dozen, - - -	18.2	1.37	.32	.17	.14	—	910
Eggs, 15c. per dozen, - - -	11	2.27	.53	.28	.23	—	1490
Milk, 8c. per quart, - - -	4	6.25	.81	.23	.25	.29	2020
Milk, 6c. per quart, - - -	3	8.33	1.08	.30	.33	.39	2675
Milk, 4c. per quart, - - -	2	12.50	1.63	.40	.50	.59	4065
Butter, - - - -	35	.71	.64	.01	.60	—	2550
	{ 30	.83	.74	.01	.71	—	3015
	{ 25	1.00	.90	.01	.85	.01	3625
Cheese, whole milk, - - -	18	1.38	.96	.40	.49	.02	2850
	15	1.67	1.17	.47	.59	.03	3420
	12	2.08	1.45	.59	.72	.04	4210

TABLE 64.—(Continued.)

FOOD MATERIALS AS FURNISHED.	Prices per Pound.	TWENTY-FIVE CENTS WILL PAY FOR					
		Total Food Materials.	Nutrients.				Calories of Potential Energy.
			Total.	Protein.	Fats.	Carbo- hydrates.	
<i>Vegetable Foods.</i>	Cents.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cals.
Potatoes, \$1.00 per bushel, -	1.7	14.70	.31	.03	.01	.26	580
Potatoes, .80 per bushel, -	1.25	20.00	.42	.04	.02	.36	790
Potatoes, .50 per bushel, -	0.85	29.40	.62	.06	.03	.53	1225
Sweet potatoes, - - -	5	5.00	.14	.00	.00	.13	240
	3	8.33	.24	.01	.00	.22	430
Beets, - - - - -	2	12.50	.14	.02	.00	.11	240
	1	25.00	.29	.04	.00	.22	485
Turnips, - - - -	2	12.50	.13	.02	.00	.10	225
	1	25.00	.27	.03	.01	.21	490
Sugar, - - - - -	5	5.00	4.90	.00	.00	4.89	9095
	6	4.17	3.64	.96	.09	2.47	6760
Dried beans, - - -	5	5.00	4.37	1.15	.10	2.96	8065
	4	6.25	5.46	1.44	.13	3.70	11110
	3	8.33	7.08	.77	.32	5.88	13720
Maize "corn" meal, - -	1	25.00	21.25	2.30	.95	17.65	41115
Oatmeal, - - - -	5	5.00	4.61	.74	.36	3.42	9255
	4	6.25	5.47	.69	.07	4.68	10285
Wheat flour, - - -	3.5	7.14	6.25	.79	.08	5.35	11755
	3	8.33	7.29	.92	.09	6.24	13695
Wheat bread, - - -	7	3.57	2.42	.31	.06	2.01	4570
	5	5.00	3.38	.44	.09	2.82	6445
Crackers, - - - -	12	2.08	1.91	.21	.20	1.47	3970
	8	3.13	2.88	.32	.29	2.21	5930
DIETARY STANDARDS.							
Man with light exercise, - - -	-	-	1.32	.22	.22	.88	2980
Man with moderate muscular work, - -	-	-	1.55	.28	.28	.99	3520
Man at active muscular work, - - -	-	-	1.76	.33	.33	1.10	4060

People who can afford it, the world over, will have animal foods and will compete with one another in the prices they give for them. In general, the animal foods are more easily and completely digested than vegetable. There is doubtless good ground for paying somewhat more for the same quantity of nutritive material in the animal food.

For persons in good health the foods in which the nutrients are most expensive are like costly articles of adornment. People who can well afford them may be justified in buying them, but they are not economical.

WASTE OF FOOD.

We waste food in two ways: We throw away a great deal and we, or at least many of us, eat more than we need. That which is thrown away in the form of kitchen and table refuse does no harm, and in so far as it is used for feeding animals, or, in the case of fat, for making soap, it is not an absolute loss. That which we consume in excess of our needs is worse than wasted, because of the harm it does to health.

In connection with the studies of dietaries cited in the previous pages, some observations have been made which bear upon this prevalent habit of throwing away valuable food. Thus, in the dietary of a carpenter, 7.6 per cent. of the total food purchased was left in the kitchen and table wastes. The total waste was somewhat worse than this proportion would imply, because it consisted mostly of the protein and fats, which are more costly than the carbohydrates. The waste contained about one-tenth of the total protein and fat, and only one-twenty-fifth of the total carbohydrates of the food; or, to put it in another way, the food purchased contained nearly 10 per cent. more protein, 12 per cent. more fat, and 5 per cent. more carbohydrates than were eaten; and worst of all, for the pecuniary economy or lack of economy, the wasted protein and fats were mostly from the meats, which supplied them in the costliest form. At the rate in which the nutrients were actually eaten in this dietary, the protein and fats in the waste would have each supplied one man for a week, and the carbohydrates for three days.

Among the dietaries of which details were given by Mr. C. D. Woods in the Annual Report of this Station for 1891, was that of a boarding house in Middletown. From the statistics of the amounts and composition of the table and kitchen wastes it appears that these contained one-ninth of the whole nutritive material of the food purchased. They included one-fifth of the protein and fats and one-twentieth of the carbohydrates. The protein and fats are costlier than the carbohydrates at best, and here again the rejected portions were mostly from the meats which supply them in the costliest forms. Except in so far as parts of the waste were fed to chickens or possibly used for soap, it was simply thrown away. The boarding house was a very good one, the mistress was counted an excellent housekeeper, and the boarders were mechanics and other thrifty and industrious people with only moderate incomes.

In the studies of dietaries of students' clubs in Middletown, referred to in the report of the Station for 1891, Mr. C. S. Videon had occasion to collect data regarding the meats used. Since not the whole of the meat was eaten, it was necessary to determine the weight and composition of the rejected portion. In buying meat in the retail markets in this region it is a common practice to have the bone and considerable of the fat cut out and left. In thus removing the "trimmings" the butcher is apt to cut out considerable else than the bone and the fat, as an observation by Mr. Videon illustrates. In a piece of roast beef weighing 16 pounds, the "trimmings," which consisted of the bone and the meat cut out with it, and which were left for the butcher to sell to the soapman or get rid of as he might otherwise choose, weighed $4\frac{1}{2}$ pounds, so that $11\frac{1}{2}$ pounds of meat went to the consumer, who, of course, paid for the whole. The butcher said that he sold this sort of beef largely to the ordinary people of the city—mechanics, small tradesmen and laborers; that many of his customers preferred not to take the "trimmings" and that they were not exceptionally large in this case, either in amount or in proportion of meat and bone, for that "cut" of beef, which was the "rib-roast." Inquiries of other meat-men brought similar information.

The $4\frac{1}{2}$ pounds of "trimmings" consisted of, approximately, $2\frac{1}{4}$ pounds of bone and $\frac{1}{2}$ pound of tendon ("gristle"), which would make a most palatable and nutritious soup, and $1\frac{3}{4}$ pounds of meat, of which 1 pound was lean and $\frac{3}{4}$ pound fat. Mr. Videon estimates that the nutritive materials of meat thus left unused, saying nothing of the bone and tendon, contained some 15 per cent. of the protein and 10 per cent. of the potential energy of the whole. The price of the beef was \$2.24. Assuming the nutritive value of the ingredients of the "trimmings" to be $12\frac{1}{2}$ per cent. of the whole, 28 cents worth of the nutritive material, besides the bone and tendon, was left at the butcher's.

In this connection I may perhaps be permitted to repeat some further statements which have been made in another place.* Dr. S. A. Lattimore, Professor of Chemistry in the University of Rochester, New York, tells me that while a member of the Board of Health of that city he directed the officer in charge of the collection of garbage to note the character of the waste material. It was ascertained that from the streets inhabited by the well-to-do

*Century Magazine, January, 1888.

classes, where the culinary affairs were largely left to the servants, the amount of waste thus collected was enormous, and that a considerable proportion of the food purchased was literally thrown away by careless servants. A surprisingly large amount of this waste consisted of good bread. Among the people in moderate circumstances this waste was less.

Still, people of moderate means do not save as they might. A gentleman from Pennsylvania, who has for years been in the way of employing hundreds of mechanics and other laborers, tells me that in passing by the houses where his employes live he is constantly pained to notice the evidences of waste of food which would not occur in his own household.

Concerning the amounts of food which we waste by excessive eating, much was said in the last Annual Report of the Station, and the subject is referred to beyond. It will, therefore, suffice to say here that the statistics at hand imply that we eat a large excess of the fatter kinds of meats, and of sugar and other sweetmeats.

Is not the American, of all civilized men, the most wasteful, and is not his worst wastefulness in his food—and drink?

The common saying that "the average American family wastes as much food as a French family would live upon," is a great exaggeration, but the statistics cited show that there is a great deal of truth in it. Even in some of the most economical families the amount of food wasted, if it could be collected for a month or a year would prove to be very large, and in many cases the amounts would be little less than enormous.

We endeavor to make our diet suit our palate by paying high prices in the market, rather than by skillful cooking and tasteful serving at home. We buy more than we need, and what makes the matter worse, it is frequently those who most need to save that are the most wasteful.

We waste at the store, at the market, and in the house, enough to make us wealthy if we would only save. The fathers and mothers do not understand the little arts of economy, and the sons and daughters do not learn them, and we are somewhat inclined to think it beneath our dignity as free-born and well-to-do American citizens to devote our attention to them. The remedy for the evil, so far as it applies to the chief item of our living expenses, our food, must be sought in two ways—in an understand-

ing of the elementary facts regarding food and nutrition, and the acceptance of the doctrine that economy is not only respectable but honorable.

THE FOOD OF THE POOR.

That the rich man becomes richer by saving, and the poor man poorer by wasting his money, is one of the commonest facts of experience. It is the poor man's money that is the most uneconomically spent in the market, and the poor man's food that is worst cooked and served at home.

I can refer only to a single phase of this subject here, repeating for the purpose a few statements from an article on "Food Consumption" in the Report of the Massachusetts Labor Bureau for 1886:

"The agents of the Bureau in collecting the statistics of dietaries have made inquiries of tradesmen as to the kinds of food the poor of Boston purchase and the price they pay. . . .

"By poor people is meant those who earn just enough to keep themselves and families from want. When a groceryman or a marketman is asked, 'What is your experience in dealing with your poor customers in regard to the quality of food used by them?' the answer is, in almost every case, 'Oh, they usually want the best and pay for it, and the most fastidious are those who can least afford it.'

"In the matter of beef, for instance, the cuts most used for steak are the face of the round, costing from eighteen to twenty cents per pound; the tip of the sirloin, at from twenty to twenty-five cents; and rib-roast, at from eighteen to twenty cents. They do not use the flank-piece for steak, and would feel insulted if it were offered them. The flour they use is the best. For butter they pay from twenty-eight to thirty cents per pound at present prices. All their other groceries are such as are sold to first-class customers."

I took occasion some time since to make inquiries myself among the Boston marketmen. One very intelligent butcher, in Boylston Market, said:

"Across the street over there is an establishment which employs a good many seamstresses. One of them comes to my place to buy meat, and very frequently gets tenderloin steak. I asked her one time why she did not take round or sirloin, which is a great deal cheaper, and she replied, very indignantly: 'Do you suppose because I don't come here in my carriage I don't want just

as good meat as rich folks have?' And when I tried to explain to her that the cheaper meat was just as nutritious, she would not believe me. Now Mr. — and Mrs. —, who are among the wealthy and sensible people of this city, buy the cheaper cuts of meat of me. Mr. — very often comes and gets a soup bone, but I have got through trying to sell these economical meats to that woman and others of her class."

I am told that the people in the poorer parts of New York City buy the highest priced groceries, and that the meat-men say they can sell the coarser cuts of meat to the rich, but that people of moderate means refuse them. I hear the same thing in Washington and other cities. Indeed, to one who looks into the matter, it is surprising as it is pathetic to see how much people of limited incomes lose by such bad economy. Here it is sadly true that, "to him that hath shall be given, and from him that hath not shall be taken away even that which he hath."

FOOD AND HEALTH.

The studies of dietaries thus far made are not sufficient for entirely reliable inferences regarding the eating habits of the people at large. The total number of dietaries examined is only a little over fifty. They have been confined mostly to New England, only a small number of the examinations have been made with the needed accuracy, and it is worth noting that the ones in which the amounts and composition of the food have been most accurately determined are for the most part the ones in which the quantities were smallest, although some of the largest of the figures obtained were thought to represent very nearly the actual quantities.

Taking the results as they are, they very decidedly confirm the general impression of hygienists that our diet is one-sided and that we eat too much. As a result of a great deal of observation and experiment, physiologists have set up certain dietary standards which are intended to indicate in a general way the proportions of the different nutritive materials of food that are appropriate to people in different conditions of life. The dietaries here examined differ widely from these standards.

If we are to take the statistics which are summarized on page 173 as a fair indication of our eating-habits, our diet is one-sided; the food which we actually eat, leaving out of account that which we throw away, has relatively too little protein and too much fat,

starch and sugar. This is due partly to our large consumption of sugar and partly to our use of such large quantities of fat meats. In the statistics referred to, the quantities of fat in the European dietaries range from one to five ounces per day, while in the American the range is from four to sixteen ounces. In the daily food of well-to-do professional men in Germany, who were amply nourished, the quantity of fat is from three to four and one-half ounces per day; while in the dietaries of Americans in similar conditions of life it ranges from five to seven and one-half ounces in the food purchased. The quantities of carbohydrates in the European dietaries range from nine to twenty-four ounces, while in the corresponding American dietaries the carbohydrates were from twenty-four to sixty ounces.

Chemists estimate the proportion of fuel ingredients to protein in what is called the "nutritive ratio." In this estimate one part by weight of fats is counted as equivalent to two and one-quarter of carbohydrates. Adding the two together gives the amount of the fuel ingredients. In the American dietaries the proportion of fuel ingredients to one part of protein ranges from six and six-tenths to eight and two-tenths, and even higher. In the European dietaries of well-nourished people and in the dietary standards which express the average needs according to the teachings of the best physiological observations, it is from four and one-tenth to six or thereabouts. The rejection of so much of the fat of meat at the market, and on our plates at the table is not mere willfulness. It is in obedience to nature's protest against a one-sided and excessive diet.

The dietary standards most commonly quoted are those of Prof. Voit, of Munich, Germany. The figures on page 173 show amounts of food consumed far in excess of these. They surpass even the liberal standards proposed tentatively by myself.

How much harm is done to health by our one-sided and excessive diet, no one can say. Physicians tell us that it is very great. Of the vice of over-eating, as practised by the well-to-do classes, in England especially, Sir Henry Thompson, a noted English physician and authority on this subject, says:

"I have come to the conclusion that more than half the disease which embitters the middle and latter part of life is due to avoidable errors in diet, . . . and that more mischief in the form of actual disease, of impaired vigor, and of shortened life accrues to civilized man . . . in England and throughout central Europe from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."

FOOD, WORK AND WAGES.

But there is another side to this story. It is found in the comparison of the food of wage-workers here and in Europe. The American workingmen, whose dietaries have been studied here, were better nourished by half than their trans-Atlantic brethren in like occupations. It looks as though ordinary people have with us what only the exceptionally well fed have on the continent of Europe, the food they need to make the most of themselves and their work. Indeed, is it not safe to say that so far as the facts at hand go, they imply very distinctly that to the American workingman is vouchsafed the priceless gift which is denied to most people of the world, namely, the physical conditions, including especially the liberal nourishment, which are essential to large production, high wages and the highest physical existence, and that as a corollary he has a like peculiar opportunity for intellectual and moral development and progress?

NEED OF RESEARCH.

In all this discussion, and the questions are fundamental for our home life, our national economy, and for our social and moral welfare, there is one difficulty. The subject is new, and definite information is wanting. The great need is for abstract inquiry. The underlying problems are the conservation of matter and the conservation of energy in the living organism. We shall not be able to tell how to get the most nutriment for our money and how to fit our food to our actual needs until these problems are more nearly solved. It is the old story, so true and yet so hard to make people believe—that the knowledge which, on the surface seems least practical, is really the most indispensable and the most useful. Part of the inquiry that is wanted can and doubtless will be carried on at public cost, but the kind which reveals the fundamental laws of biological chemistry requires the atmosphere and the appliances of the university, and can be accomplished only by the endowment of research.

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STATE OF CONNECTICUT.

—...—
SIXTH ANNUAL REPORT

—OF THE—

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1893.

—...—
Printed by Order of the General Assembly.

—...—
MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
1894.

PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications should be addressed to

STORRS AGRICULTURAL

EXPERIMENT STATION,

STORRS, CONN.

Tolland County.

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— OF THE —

STORRS AGRICULTURAL COLLEGE.

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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural College. The chemical and other more abstract work is carried out at Wesleyan University, Middletown.

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EXECUTIVE COMMITTEE.

T. S. GOLD, West Cornwall,	}	-	-	-	-	}	<i>Of the Board of Trustees of</i>
J. M. HUBBARD, Middletown,	}	-	-	-	-	}	<i>Storrs Agricultural College.</i>
B. F. KOONS, Storrs,	-	-	-	-	-	-	<i>President of the College.</i>

TREASURER.

HENRY C. MILES, Milford.

STATION STAFF.

W. O. ATWATER, Middletown,	-	-	-	-	-	-	-	-	<i>Director.</i>
C. D. WOODS, Middletown,	-	-	-	-	-	-	-	-	<i>Vice-Director and Chemist.</i>
C. S. PHELPS, Storrs,	-	-	-	-	-	-	-	-	<i>Agriculturist.</i>
E. B. FITTS, Storrs,	-	-	-	-	-	-	-	-	<i>Assistant in Farm Experiments.</i>

Report of the Executive Committee.

To His Excellency Luzon B. Morris,

Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly, approved March 6th, 1889, relating to the publication of Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Sixth Annual Report of that Station, namely, that for the year 1893.

The Committee refer to the accompanying report of the Treasurer for details of expenditure, and to that of the Director and his associates for the history of the work accomplished, and express their confident belief that the funds have been wisely expended and that the work is such as will result in great benefit to our agricultural interests.

Respectfully submitted,

T. S. GOLD,	} <i>Executive Committee.</i>
J. M. HUBBARD,	
B. F. KOONS,	

REPORT OF THE TREASURER.

7

Chemicals, - - - - -	\$93 28
Coal, gas and oil, - - - - -	193 34
Hardware and lumber, - - - - -	16 36
Freight, express and cartage, - - - - -	157 07
Dietary investigations, - - - - -	39 52
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Incidentals, - - - - -	54 45
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	\$8,131 42

HENRY C. MILES,

Treasurer,

This certifies that we have examined the accounts of Henry C. Miles, Treasurer of the Storrs Agricultural Experiment Station, for the fiscal year ending June 30th, 1893, and compared them with the vouchers, and find the same correct. The balance in hands of the Treasurer on June 30th, 1893, amounted to Three Dollars and Seventy-six cents (\$3.76).

E. LIVINGSTON WELLS, } *Auditors of*
 OSCAR LEACH, } *Public Accounts.*

HARTFORD, December 26th, 1893.

Report of the Director

FOR THE YEAR 1893.



The principal lines of inquiry prosecuted during the past year may be concisely stated as follows:

1. Meteorological observations.
2. Field experiments with fertilizers.
3. Experiments on the growth of forage plants.
4. Feeding experiments with sheep.
5. Digestion experiments with sheep.
6. Studies of rations fed to milch cows on dairy farms in Connecticut.
7. Studies of bacteria and their action in the ripening of cream.
8. Analyses of feeding stuffs.
9. Investigations of materials used for the food of man. Analyses of foods exhibited at the World's Fair.
10. Investigations of dietaries.
11. Experiments with the bomb calorimeter.
12. Development of a respiration calorimeter.

The larger part of the work done during the year is in continuation of that described in previous reports of the Station. The digestion experiments with sheep; the studies of the feeding practice of Connecticut dairymen; the investigations of foods undertaken at the World's Fair in behalf of the Columbian Commission; and the work with the bomb and respiration calorimeters represent new inquiries. The new work, like much of that previously begun, has to do chiefly with the chemistry of nutrition.

For an institution with an annual income of only \$7,500 per year, which is the whole amount received by the Storrs Station

from public sources, so wide a range of subjects of investigation might seem inexcusable. The justification is found in two facts. One is that the several lines of investigation upon the food and nutrition of animals and man are more or less nearly parallel with each other and are so conducted as to form really one department of inquiry. The other is that a considerable part of the work is done with little or no expense to the Station treasury. Free use is had of rooms and apparatus in the chemical laboratory of Wesleyan University, whose trustees are desirous of promoting scientific research, especially that of the more abstract kind to which an already large and gradually increasing part of the investigations belongs. The calorimetric investigations especially are of this order. The studies of dietaries are made in coöperation with the U. S. Department of Labor, which bears a large part of the expense. The cost of the investigations of foods exhibited at the World's Fair is borne mainly by the Bureau of Awards of the Columbian Commission. Considerable sums have been given from time to time by private individuals in aid of different parts of the more purely scientific inquiry. Though these sums have been placed in charge of the treasurer of Wesleyan University they have been applied directly to the payment of the expenses of the inquiries, the results of which have been and are to be published in the Reports of the Station. And finally, a considerable amount of service has been rendered gratuitously. This is notably the case with the bacteriological investigations of Prof. Conn which bear so directly upon the dairy industry. It is certainly the belief of many friends of the Station that its efficiency is doubled by what comes to it outside of the government appropriation.

Abstract research is the necessary foundation of the most useful knowledge and a large amount of it is being carried on in connection with the work of the Station. Partly because we have but little completed research of this kind to report now, and partly because it is of less interest to practical men, almost none is given here. The whole of the contents of the present Report have to do with things of everyday interest. And I may add that while the subjects reported upon bring less of new conclusions than have been found in several previous Annual Reports, no year in the history of the Station has been marked by so much of active and really fruitful work. The following brief statements will give an idea of the character of the year's work.

FIELD EXPERIMENTS WITH FERTILIZERS.

As in preceding years, these have been conducted upon the Station land and by farmers upon their own farms in different parts of the State in coöperation with the Station. "The object aimed at is to study the soils of different regions, learn their deficiencies, and find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical way." The results of the year's work are given by Professor Phelps upon pages 119 to 139 of this Report. Owing to the drought in mid-summer, the results are not so striking as they have been in other years.

The experiments by Mr. Dean of Lime Rock are particularly instructive. They cover a period of five years during which the same plots have received the same fertilizers but have borne different crops in different years. The principal lessons taught are summarized by Professor Phelps as follows:

"(1). The necessity of preparing fertilizers so as to meet the needs of soils.

"(2). The importance of stocking light, porous soils with a large amount of organic nitrogen in order to supply nitrogen to the crop and get the best results from the mineral fertilizers.

"(3). The value and economy of legumes for improving light, porous soils by plowing in as manure.

"(4). The evidence that soluble phosphates may prove a detriment to the crop on certain light soils, unless there is an abundance of available nitrogen present in the soil. In the absence of available nitrogen, the phosphates seem to hasten maturity and thus shorten the life of the plant. This is a probable explanation of the way the phosphoric acid diminishes the yield."

A summary of the results of fifteen years' experimenting by soil tests with fertilizers on farms throughout New England, was given in Bulletin No. 10 of the Station, and in the Annual Report for 1892.

FORAGE PLANTS.

The question of forage plants for Connecticut farming has been studied by the Station ever since its establishment. Different species and varieties are grown in small areas in the Forage Garden, and those which seem to be worthy of special study are cultivated on a larger scale. During the past two or three years especial attention has been given to the effects of nitrogenous

fertilizers upon the composition of the crop. The results upon grasses up to 1892 were given in pages 60-66 of the Report of the Station for that year. It is found not only that nitrogenous fertilizers increase the total yield of grasses, but also that the percentage of protein in them is larger, so that the value of the crop is increased in a two-fold way.

During 1893 especial attention was given to legumes. This work will be repeated and enlarged the coming year, and the results are accordingly reserved for later publication. Meanwhile it may be said that the experience of the Station serves to emphasize and explain the importance of leguminous plants. The statements (See Bulletin 6 of the Station) will bear constant repetition, that the legumes are especially valuable because of:—

1. Their large percentage of protein compounds which serve to form blood, muscle, bone and milk, and their consequent feeding value, which exceeds that of the grasses, corn fodder, corn stover, or straws. They may be used to supplement these fodders, in place of the concentrated nitrogenous feeds, such as bran, cotton seed, linseed, and gluten meals, etc. Hay from the legumes is twice or more than twice as rich in protein as that from the grasses.

2. Their power of gathering large quantities of plant food from natural sources. Many, if not all of our common legumes acquire considerable quantities of nitrogen from the air. Their roots penetrate deeply into the subsoil, and they thus obtain plant food from depths beyond the reach of plants with smaller root development.

3. Their manurial value. When the crop is fed, most of the nitrogen, phosphoric acid, potash and other fertilizing ingredients go into the excrement, liquid and solid, and if preserved, make a rich manure. If the crop is plowed under, its plant food, including that acquired from the air and gathered from the subsoil, becomes available for succeeding crops. The large amounts of plant food left behind in roots and stubble after the removal of the crop, furnish a cheap and valuable store of plant food for following crops.

Among the legumes which the experience of the Station leads us to commend for trial in the State are clovers, including scarlet clover, cow peas, vetch and soy beans.

FEEDING EXPERIMENTS WITH SHEEP.

The object of these has been to observe the effects of different kinds of food upon the production of fat and lean flesh in sheep. Lambs of the same age and breed and as nearly alike as could be obtained, were divided into three groups, numbered one, two and three. Those of group three were butchered at the beginning of the experiment. The other two groups were fed for three months upon different rations; group two having a "narrow" ration (rich in protein), and group three a "wide" ration (rich in carbohydrates). The results are given by Messrs. Woods and Phelps on pages 28-42 of the present Report. The work is being continued during the winter of 1893-4, and the details of the practical deductions are reserved for future publication. In general it appears that, as was to be expected from experiments elsewhere, a reasonably large allowance of protein in the fodder is desirable. The results tend to confirm the belief that Connecticut farmers need to increase the proportion of nitrogen in their feeding stuffs.

DIGESTION EXPERIMENT WITH SHEEP.

The greatest difficulty in the experiments just referred to on feeding sheep with mixed rations was to calculate the amount of food actually digested by the animals. In order to overcome this difficulty as far as possible, several digestion experiments with the same kinds of food were undertaken with animals of the same breed, age and weight as those of the feeding experiment. This study was begun in the fall of 1893. The results could not be made ready for printing in the present Report. They are therefore reserved for later publication.

BACTERIA IN THE RIPENING OF CREAM.

During the past six years investigations on the Bacteria of Milk have been conducted in behalf of the Station by H. W. Conn, Professor of Biology in Wesleyan University.* The results of practical trials of artificial cultures upon the ripening of cream and other related topics are discussed by Prof. Conn upon pages 43-68 of this Report. The principal points are there summarized as follows:

* Some of the results have been given in the publications of the Station, as follows: Bacteria in Milk, Cream and Butter, Bulletin 4, and Annual Report for 1889, pp. 52-67. Ripening of Cream, Annual Report for 1890, pp. 136-157. A Micrococcus of Bitter Milk, Report for 1891, pp. 158-162. The Isolation of Rennet from Bacteria Cultures, Report for 1892, pp. 106-126. See also The Fermentations of Milk, Experiment Station Bulletin No. 9 of the Office of Experiment Stations of the U. S. Department of Agriculture.

1. Different species of bacteria grown in the cream while ripening have different effects upon the butter flavor. The differences in the resulting butter aroma are not very prominent in most cases, but are decided enough to make the difference between a first-class grade of butter and a second-class.

2. Pasteurizing cream at 70° C. (*i.e.*, heating to 158° Fahrenheit for two or three minutes), will so largely destroy the bacteria in it, that a pure culture of bacteria subsequently inoculated will produce its proper effects, not materially affected by the few organisms left in the cream after pasteurization.

3. Most species of bacteria found in cream of a good creamery produce good butter. The number which injure the flavor of the butter is small.

4. No one species of those experimented with, when used alone for ripening cream, produces a typically flavored butter, though many of them produce butter which is excellent in flavor and which was preferred to that of the normal ripening.

One species of bacteria for ripening cream has been furnished to three creameries. At the time of the present writing the experience with it has covered a period of several weeks in each of two, and nearly four months in one, of the creameries, that in Cromwell, Conn. The managers report most gratifying results. Those with the longest experience are the most enthusiastic. In the Cromwell creamery the use of a culture furnished by Prof. Conn has greatly improved the quality of the butter. There seems to be the best reason to expect that bacteria cultures may be made a most important help in butter-making. With the right bacteria the finest butter, that with the most desirable aroma and flavor, can be made. It ought to become possible to select the desirable kinds of bacteria and supply them for use and thus improve the quality of our butter, just as our field and garden crops and fruits have been improved by selection of the best varieties. If experience justifies this expectation the benefit to dairying will be very great.

RATIONS FED TO MILCH COWS IN CONNECTICUT.

During the winter of 1892-3 a Station representative visited sixteen different dairy farms in different parts of the State, and studied the methods practiced in the management of their herds. Information was obtained regarding:—number of animals kept; breed, age and weight of each cow; period of lactation; milk flow

at each milking; percentage and weight of fat in milk; weight of each kind of feeding stuff fed per cow per day, and the chemical composition of the feeding stuffs.

A full description of these tests, together with a practical discussion of the results is given by Messrs. Woods and Phelps on pages 69-115 of this Report. Statements of rations actually fed are summarized on pages 103-115, with suggestions of changes that might be made and of particular rations for special cases.

This is only the beginning of an effort by the Station to coöperate directly with dairymen in the study of the methods of feeding their cows and the ways by which improvements may be made. The purpose of this work is parallel with that of the coöperative field experiments by farmers for studying the effects of fertilizers upon the crops grown on their own farms. The experiments with fertilizers have proven most useful from both the educational and the practical standpoints. It is hoped that the work on methods of feeding may be equally so.

FEEDING STUFFS USED IN NEW ENGLAND.

On pages 140-173 Mr. Woods has summarized briefly the results of the analyses of feeding stuffs grown in New England and the grains chiefly used for feeding in the same section. He has also summarized the results of tests of the digestibility of these materials by experiments with animals in Europe and in the United States, and has added a short explanation of the methods employed in calculating rations.

ANALYSES OF FEEDING STUFFS.

A considerable number of feeding stuffs have been analyzed in connection with feeding experiments upon the growth of plants. The results of 146 analyses, together with brief descriptions of the specimens, are given on pages 17-27 of this Report.

INVESTIGATIONS OF FOODS. ANALYSES OF FOOD MATERIALS EXHIBITED AT THE WORLD'S FAIR.

In connection with the studies of dietaries, a considerable number of food materials have been analyzed. The principal work in this direction during the past year, however, has been in the analyses of foods exhibited at the World's Fair.

As a member of the Jury of Awards at the Fair the writer was assigned to the department which included food products, and was requested by the Executive Committee on Awards to take

charge of an examination of some of the more interesting and important materials there exhibited. This investigation was made in accordance with the purpose of the World's Columbian Commission, which was to make the Fair educational and to provide that its influence should continue after the Fair itself should end. Probably no other occasion has offered such an opportunity for comparison of materials used for the nutrition of man. Certainly none has been so favorable for collecting specimens of food materials which are most interesting to us in the United States. An examination of cereal grains was made under the direction of Professor Wiley, Chemist in the U. S. Department of Agriculture. The prepared food products as such, including especially the animal foods, were assigned to myself.

By the courtesy of the authorities of the University of Chicago, the use of the chemical laboratory of that institution was given for the investigation. In order to save the expense of apparatus and the time required for preparing it, the trustees of the Storrs Station authorized the use of its material for the purpose, and more than a ton of packages of apparatus and chemicals was shipped from Middletown to Chicago and used in the investigation. Mr. Woods, the Vice-Director of the Station, assumed for a time the immediate charge of the analyses. Messrs. H. B. Gibson, H. M. Smith, F. W. Frost, A. E. Loveland, and H. M. Burr, who had been previously connected with the work of the Experiment Station or with that of the chemical laboratory of Wesleyan University; and Dr. C. F. Langworthy and Mr. E. L. Sturtevant, who have since become associated with the chemical laboratory, and Mr. O. S. Blakeslee of the physical laboratory, accompanied me to Chicago to share in the work. The services of a number of other gentlemen were secured so that, all told, 16 chemists, representing 12 American and foreign colleges and universities, were occupied there for a longer or shorter time during the summer. Somewhat over 600 specimens of food materials were collected. The analyses were made, so far as possible, in Chicago during the Fair. At its close the work was transferred to Middletown, where it has been continued with the aid of the Station and of Wesleyan University. Analyses of 500 specimens have been completed and a report of the work is now being prepared. The investigation is thus more extensive than any previously undertaken.

STUDIES OF DIETARIES.

These have been of the same general character as those described in previous Reports of the Station and are in continuation of an investigation which is being made by coöperation with the U. S. Department of Labor.

INVESTIGATIONS OF THE BOMB CALORIMETER.

The study of food and nutrition has brought us to a point where it is essential to learn the fuel value of food materials, or in other words, the amounts of potential energy which they contain and which may be changed to heat or the muscular power or other form of energy in the body. The apparatus for this purpose is called the calorimeter. Investigations with a form of calorimeter were described in the Report for 1890. A form which has proven more satisfactory is the so-called bomb calorimeter. Hitherto the only satisfactory bomb calorimeter has been that of Berthelot, but its great cost, \$1,000 or more, which is due to the large quantity of platinum required for its construction, has prevented its general use. With the aid of Prof. Hempel, of Dresden, I have succeeded in obtaining a bomb calorimeter which costs not more than \$100 or \$200, and proves quite satisfactory. The effort is now being made to devise one which shall be less expensive.

RESPIRATION CALORIMETER.

Research upon nutrition has brought us to the point where the study of the application of the laws of the conservation of matter and of energy in the living organism are essential. That is to say, we must be able to determine the balance of income and outgo of the body, and this balance must be expressed both in terms of matter and of energy. For this purpose a respiration calorimeter is being devised. This is an apparatus in which an animal or a man may be placed for a number of hours or days and the amounts and composition of the food and drink and inhaled air; the amounts and composition of the excreta, solid, liquid and gaseous; the potential energy of the materials taken into the body and given off from it; the quantity of heat radiated from the body; and the mechanical equivalent of the muscular work done are all to be measured. The experimenting is complicated, costly and time-consuming. The results already obtained are, however, very encouraging in their promise of future success.

W. O. ATWATER.

RESULTS OF ANALYSES OF FODDERS AND FEEDING STUFFS.

BY CHAS. D. WOODS.

In connection with the work of the Station, analyses of the following miscellaneous feeding stuffs have been made by the Station chemists. For the most part the analyses were made in connection with feeding experiments or experiments upon the growth of plants. In no case were they undertaken merely to increase the amount of this class of data. The methods of analyses recommended by the Association of Official Chemists were employed.

The results of the analyses as calculated to water content at harvest or at the time of analyses are given in table 1, page 21, which follows the description of samples. In this table the materials are grouped somewhat according to their water content at time of taking samples as follows: Green fodders; silage; field-cured hay; cured hay and fodder; grain; and milling products. This order is also observed in the descriptions of samples.

The results calculated to water-free (dry matter) as the basis are given in table 2, page 24.

The potential energy, or fuel value, of a pound of each of the feeding stuffs as given in the tables, was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6, and the number of hundredths of a pound of fat by 42.2, and taking the sum of these three products as the number of calories of potential energy in the materials.*

DESCRIPTION OF SAMPLES.

In the description of samples the same order of arrangement is observed as in table 1.

GREEN FODDERS.

1218-1221, *Oat Grass (Avena elatior)*.—Grown in grass garden in 1893. The sample was taken June 24th, at which time the seeds were beginning to form. There was a fair yield of quite pure oat grass. No. 1218 was from a plot without fertilizers. No. 1219 was from a plot supplied with dissolved bone-black at the rate of 320 pounds per acre, and with muriate of potash at the rate

* See article on fuel value of feeding stuffs, Report of this Station, 1890, pages 174-181.

of 160 pounds. No. 1220 was from a plot to which "mixed minerals" were applied as in 1219, and had in addition 160 pounds of nitrate of soda per acre. No. 1221 was grown on a plot to which mixed minerals were applied as in 1219, and had in addition 480 pounds of nitrate of soda per acre.

1222-1225, *Fescue Grass* (*Festuca elatior*).—Grown in the grass garden of the Station in 1893. The samples were taken June 24th, at which time the grass was in full bloom. No. 1222 was from a plot without fertilizers. No. 1223 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1224 was grown on a plot to which mixed minerals were applied as in 1223, and had in addition 160 pounds of nitrate of soda per acre. No. 1225 was grown on a plot to which mixed minerals were applied as in 1221, and had in addition 480 pounds of nitrate of soda per acre.

1226-1229, *Orchard Grass* (*Dactylis glomerata*).—Grown in the grass garden of the Station in 1893. The samples were taken June 24th, at which time the grass was a little past bloom. No. 1226 was grown without the use of fertilizers. No. 1227 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1228 was grown on a plot to which mixed minerals were applied as in 1227, and had in addition 160 pounds of nitrate of soda per acre. No. 1229 was grown on a plot to which mixed minerals were applied as in 1227, and had in addition 480 pounds of nitrate of soda.

1230-1233, *Timothy* (*Phleum pratense*).—Grown in the Station grass garden in 1893. The samples were taken July 1st, at which time the grass was in early bloom. No. 1230 was grown without the use of fertilizers. No. 1231 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1232 was grown on a plot to which mixed minerals were applied as in 1231, and had in addition 160 pounds of nitrate of soda per acre. No. 1233 was grown on a plot to which mixed minerals were applied as in 1231, and had in addition 480 pounds of nitrate of soda per acre.

1234-1245, *Cow Pea Vines* (*Dolichos sinensis*).—Grown in a soil test experiment on the Station grounds in 1893. Nos. 1234, 1235 and 1236 were from plots which received no fertilizers. The plot from which 1237 was taken received nitrate of soda at the rate of 320 pounds per acre; that of 1238, dissolved bone-black at the rate of 320 pounds per acre; 1239, muriate of potash at the rate of 160 pounds per acre; 1240, 160 pounds of nitrate of soda and 320 pounds of dissolved bone-black per acre; 1241, 160 pounds of nitrate of soda and 160 pounds of muriate of potash per acre; 1242, 320 pounds of dissolved bone-black and 160 pounds of muriate of potash; 1243, 160 pounds of nitrate of soda, 320 pounds of dissolved bone-black, and 160 pounds of muriate of potash per acre. No. 1244 was from a plot which received six tons of stable manure and 160 pounds of dissolved bone-black, and 1245 was from a plot which received six tons of stable manure per acre.

1246-1248, *Cow Pea Vines* (*Dolichos sinensis*).—No. 1246 was grown without the use of fertilizers. No. 1247 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre, muriate of potash at the rate of 160 pounds and nitrate of soda at the rate of 160 pounds. No. 1248 was

grown on a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre, muriate of potash at the rate of 160 pounds and nitrate of soda at the rate of 480 pounds per acre.

ENSILAGE.

1115, *Corn Ensilage*.—Sample taken in connection with milch cow ration No. 1.* Common yellow Canada corn. Good ears picked off before cutting.

1123, *Corn Ensilage*.—Sample taken in connection with milch cow ration No. 2. White southern corn, planted very thick and cut before eating.

1142, *Corn Ensilage*.—Sample taken in connection with milch cow ration No. 5. Butler's early dent corn. Ears picked off before harvesting.

1183, *Corn Ensilage*.—Sample taken in connection with milch cow ration No. 12. White southern corn.

FIELD CURED CROPS.

1249-1261, *Hungarian Grass (Setaria Italica)*.—Grown by the Station in a special nitrogen experiment in 1893. Nos. 1249 and 1250 were grown without the use of fertilizers. Nos. 1251 and 1252 were grown upon plots to which were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Nos. 1253, 1254 and 1255 were grown upon plots to which was applied in addition to the mixed minerals of the preceding, nitrate of soda at the rate of 160, 320 and 480 pounds per acre. Nos. 1256, 1257 and 1258 were grown upon plots which had, in addition to the mixed minerals, sulphate of ammonia at the rate of 120, 240 and 360 pounds per acre respectively. Nos. 1259, 1260 and 1261 were grown upon plots which had, in addition to the mixed minerals, ammonite at the rate of 192, 384 and 576 pounds per acre respectively per acre.

1127, 1137, 1144, 1150, 1153, 1168, 1176, 1188, 1194, 1198, 1205, 1210, *Mixed Hay*.—Samples taken in connection with milch cow rations Nos. 2, 4, 5, 6, 7, 10, 11, 12, 13, 14.

1156, *Mixed Hay*.—Sample taken in connection with milch cow ration No. 8. Hay unlike ordinary farm hay, being almost entirely from a large lawn.

1163, *Mixed Hay*.—Sample taken in connection with milch cow ration No. 9. Mostly timothy.

1211, *Mixed Hay*.—Sample taken in connection with milch cow ration No. 16. Poor quality, used cut up with stover.

1126, *Mixed Hay*.—Sample taken in connection with milch cow ration No. 2. Meadow hay of poor quality.

1120, *Timothy and Red-top Hay*.—Sample taken in connection with milch cow ration No. 1. Rather late cut.

1132, *Timothy and Red-top Hay*.—Sample taken in connection with milch cow ration No. 3. Early cut of good quality.

1162 and 1169, *Rowen Hay*.—Samples taken in connection with milch cow rations Nos. 9 and 10.

1178, *Rowen Hay*.—Used in sheep feeding experiment by the Station. Mostly grasses, one-sixth to one-fourth clover.

1121, *Oat Hay*.—Sample taken in connection with milch cow ration No. 1. Cut in bloom.

1149 and 1174, *Oat Hay*.—Sample taken in connection with milch cow rations Nos. 6 and 11. In each case the crop was cut for grain, but was used for hay.

* See article beyond on rations actually fed to milch cows.

MILLING PRODUCTS.

1146, 1158, 1164, 1171, 1186 and 1192, *Corn Meal*.—From samples taken in connection with milch cow rations Nos. 6, 9, 10, 11, 12, 13.*

1181, *Corn Meal*.—Sample taken in connection with sheep feeding experiment by the Station.

1135, 1155, 1202, 1209 and 1214, *Cob Meal*.—Corn and cob ground together. These samples were taken in connection with milch cow rations Nos. 2, 8, 15, 16 and 17. No. 1209 consisted of a mixture of twelve bushels of native corn on the ear and of four bushels of western corn.

1116, 1136, 1154, 1160, 1166, 1173, 1187, 1197, 1203 and 1208, *Wheat Bran*.—Samples taken in connection with milch cow rations Nos. 1, 4, 8, 9, 10, 11, 12, 14, 15 and 16.

1180, *Wheat Bran*.—Samples taken in connection with sheep feeding experiment by the Station.

1119, 1122, 1141, 1145, 1151, 1172, 1193 and 1213, *Wheat Middlings*.—These samples were taken in connection with milch cow rations Nos. 1, 2, 5, 6, 7, 11, 13 and 17.

1129, *Rye Bran*.—Sample taken in connection with milch cow ration No. 3.

1200, *Rye Meal*.—Sample taken in connection with milch cow ration No. 15.

1182, *Old Process Linseed Meal*.—Sample taken in connection with sheep feeding experiment by the Station.

1118 and 1201, *Old Process Linseed Meal*.—Samples taken in connection with milch cow rations Nos. 1 and 15.

1131, 1134, 1143, 1147, 1157, 1165, 1170, 1184 and 1191, *Cotton Seed Meal*.—Samples taken in connection with milch cow rations Nos. 3, 4, 7, 9, 10, 11, 12 and 13.

1179, *Pea Meal*.—Sample taken in connection with sheep feeding experiment by the Station.

1117, 1128 and 1207, *Buffalo Gluten Meal*.—Samples taken in connection with milch cow rations Nos. 1, 3 and 16.

1124, 1140, 1159 and 1196, *Chicago Gluten Meal*.—Samples taken in connection with milch cow rations Nos. 2, 5, 9 and 14.

1130, *Hominy Chop, Hominy Feed, Hominy Meal or Baltimore Meal*.—Sample taken in connection with milch cow ration No. 3.

1185, *Malt Sprouts*.—Sample taken in connection with milch cow ration No. 12.

1195 and 1204, *Oat Feed*.—Refuse from oat meal factory. Samples taken in connection with milch cow rations Nos. 14 and 15.

1125 and 1152, *Provender (Corn and Oats)*.—The provender was claimed to consist of two-thirds corn and one-third oats, ground together. Samples taken in connection with milch cow rations Nos. 2 and 7.

1189, *Sheep Feed*.—Sample of the grain and ensilage mixture which was being used by Mr. Charles Lyman of Middlefield in the winter of 1892. The mixture was made as follows: Corn ensilage, 4000 pounds; bran, 350 pounds; linseed meal, 150 pounds; corn, 1000 pounds; pea meal, 1000 pounds.

1139, *Shorts and Skim Milk*.—Mr. Edward Atkinson of Boston, in experimenting with the utilization of separator skim milk, evaporated it with wheat bran in the proportion of two parts of milk to one of bran by weight. The loss from evaporation was such that 16 parts of the mixture gave 7 parts of the feed.

* See article beyond on rations actually fed to milch cows.

TABLE I.

Proximate Composition of Fodders and Feeding Stuffs.—Results of Analyses Herewith Reported, Calculated to Water Content at Time of Taking Sample.

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Potential En'gy.
	<i>Green Fodders.</i>	%	%	%	%	%	%	Calor's per lb.
1218	Avena elatior, -	65.91	2.62	1.06	16.06	11.94	2.41	615
1219	Avena elatior, -	67.75	2.39	1.01	14.80	11.67	2.38	580
1220	Avena elatior, -	68.95	3.33	1.10	13.73	10.70	2.19	565
1221	Avena elatior, -	68.76	4.29	1.14	13.37	10.14	2.30	565
	Average, -	67.84	3.16	1.08	14.49	11.11	2.32	580
1222	Festuca elatior, -	70.99	2.17	.76	13.44	10.58	2.06	520
1223	Festuca elatior, -	71.29	2.23	.82	13.22	10.34	2.10	515
1224	Festuca elatior, -	74.44	2.67	.68	11.02	9.22	1.97	455
1225	Festuca elatior, -	76.28	3.35	.77	9.73	7.90	1.97	425
	Average, -	73.25	2.61	.76	11.85	9.51	2.02	479
1226	Dactylis glomerata, -	65.33	2.89	1.23	15.50	12.61	2.44	625
1227	Dactylis glomerata, -	65.64	2.66	1.18	15.47	12.41	2.64	615
1228	Dactylis glomerata, -	71.77	3.38	1.09	11.89	9.43	2.44	505
1229	Dactylis glomerata, -	76.45	3.96	1.05	9.10	7.35	2.09	425
	Average, -	69.80	3.22	1.14	12.99	10.45	2.40	545
1230	Phleum pratense, -	71.32	2.27	.94	13.86	9.88	1.73	520
1231	Phleum pratense, -	72.62	2.11	.77	13.13	9.60	1.77	495
1232	Phleum pratense, -	73.23	2.41	.74	12.38	9.58	1.66	485
1233	Phleum pratense, -	74.24	3.07	.77	11.48	8.86	1.58	470
	Average, -	72.85	2.47	.81	12.71	9.48	1.68	495
1234	Cow pea vines, -	80.81	3.28	.72	9.12	3.83	2.24	330
1235	Cow pea vines, -	82.45	3.37	.65	7.73	3.52	2.28	300
1236	Cow pea vines, -	81.25	3.53	.58	8.28	3.94	2.42	320
1237	Cow pea vines, -	82.32	3.01	.61	8.59	3.51	1.96	305
1238	Cow pea vines, -	81.58	3.49	.60	8.33	3.73	2.27	315
1239	Cow pea vines, -	84.01	3.16	.56	6.84	3.25	2.18	270
1240	Cow pea vines, -	82.59	3.00	.63	8.22	3.47	2.09	300
1241	Cow pea vines, -	84.62	2.46	.53	6.93	3.48	1.98	260
1242	Cow pea vines, -	82.95	3.39	.61	7.00	3.84	2.21	290
1243	Cow pea vines, -	84.55	2.78	.55	6.59	3.44	2.09	265
1244	Cow pea vines, -	82.83	3.29	.61	7.52	3.68	2.07	295
1245	Cow pea vines, -	83.83	2.92	.60	7.20	3.46	1.99	280
1246	Cow pea vines, -	86.07	3.03	.58	5.36	3.05	1.91	235
1247	Cow pea vines, -	86.62	2.82	.55	5.07	3.08	1.86	230
1248	Cow pea vines, -	86.28	2.75	.63	5.55	3.16	1.63	240
	Average, -	83.53	3.08	.60	7.22	3.49	2.08	280
	<i>Ensilage.</i>							
1115	Corn ensilage, -	80.18	1.91	.83	10.54	5.16	1.38	360
1123	Corn ensilage, -	81.35	1.34	.54	9.51	6.16	1.10	335
1142	Corn ensilage, -	61.54	2.33	1.11	22.19	10.40	2.43	695
1183	Corn ensilage, -	83.69	1.74	.69	7.58	5.30	1.00	300
1190	Corn ensilage, -	83.99	1.08	.67	8.81	4.55	.90	295
	Average, -	78.15	1.68	.77	11.73	6.31	1.36	395

* For description of samples, see pages 17-19.

TABLE I.—(Continued.)

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Potential En'gy.
	<i>Field Cured Hay.</i>	%	%	%	%	%	%	Calor's per lb.
1249	Hungarian grass, -	25.15	6.05	2.55	39.68	21.95	4.62	1370
1250	Hungarian grass, -	24.55	7.41	2.43	38.22	22.44	4.95	1370
1251	Hungarian grass, -	34.69	5.53	1.93	33.18	19.86	4.81	1170
1252	Hungarian grass, -	31.67	6.33	2.03	33.98	20.60	5.39	1240
1253	Hungarian grass, -	29.13	5.72	1.93	36.44	21.93	4.85	1270
1254	Hungarian grass, -	30.30	7.08	2.33	34.16	21.13	5.00	1260
1255	Hungarian grass, -	34.14	9.36	2.44	29.49	19.50	5.07	1185
1256	Hungarian grass, -	30.16	5.92	2.24	35.06	21.24	5.38	1250
1257	Hungarian grass, -	33.46	5.76	1.84	32.69	21.05	5.20	1185
1258	Hungarian grass, -	34.94	7.10	2.04	30.12	20.63	5.17	1160
1259	Hungarian grass, -	33.37	7.10	2.17	31.17	21.06	5.13	1195
1260	Hungarian grass, -	32.96	7.98	2.28	30.79	20.87	5.12	1205
1261	Hungarian grass, -	34.94	8.48	2.22	29.85	19.39	5.12	1165
	Average, -	31.50	6.91	2.18	33.45	20.90	5.06	1240
	<i>Cured Hay & Fodders.</i>							
1215	Mixed hay and stover, -	18.43	7.70	2.84	41.31	24.34	5.38	1485
1127	Hay, mixed, -	14.97	7.76	2.94	41.81	27.37	5.15	1550
1150	Hay, mixed, -	14.59	6.14	2.91	44.81	26.70	4.85	1565
1153	Hay, mixed, -	13.73	7.60	3.30	45.90	23.99	5.48	1580
1156	Hay, mixed, -	12.48	10.40	2.75	40.96	27.00	6.41	1575
1163	Hay, mixed, -	21.39	5.94	1.98	39.49	26.30	4.90	1420
1168	Hay, mixed, -	12.49	9.08	3.33	43.18	24.83	7.09	1575
1176	Hay, mixed, -	12.38	6.90	2.33	38.09	34.74	5.56	1580
1177	Hay, mixed, -	12.16	8.73	3.10	42.32	28.28	5.41	1605
1188	Hay, mixed, -	13.24	9.27	3.80	43.76	23.81	6.12	1590
1194	Hay, mixed, -	11.39	9.30	2.92	43.45	26.32	6.62	1595
1198	Hay, mixed, -	15.39	8.56	3.66	42.76	23.17	6.46	1545
1205	Hay, mixed, -	11.80	7.44	2.09	47.83	26.20	4.64	1605
1210	Hay, mixed, -	15.94	7.20	3.10	45.28	23.45	5.03	1545
1211	Hay, mixed, -	15.09	7.43	3.14	42.97	25.55	5.82	1545
1144	Hay, mixed, -	15.52	8.55	2.71	38.41	29.20	5.61	1530
1126	Hay, mixed, -	11.89	8.98	2.86	41.49	28.63	6.15	1595
1137	Hay, mixed, -	18.54	7.33	3.30	41.52	23.32	5.99	1485
	Average, -	14.30	8.04	2.95	42.59	26.40	5.72	1560
1120	Timothy and red-top, -	12.28	7.73	3.07	42.91	29.08	4.93	1615
1132	Timothy and red-top, -	15.30	5.51	2.96	45.28	26.81	4.14	1570
	Average, -	13.79	6.62	3.02	44.09	27.94	4.54	1595
1162	Rowen hay, -	21.62	12.69	3.53	35.06	21.21	5.89	1430
1169	Rowen hay, -	15.13	12.84	3.41	39.86	22.13	6.63	1535
1178	Rowen hay, -	13.73	12.80	3.08	39.90	25.24	5.07	1535
	Average, -	16.83	12.81	3.34	38.30	22.86	5.86	1515
1121	Oat hay, -	14.77	8.21	2.63	38.21	29.61	6.57	1525
1149	Oat hay, -	14.58	5.66	2.82	43.85	28.70	4.39	1575
1174	Oat hay, -	26.86	8.50	3.41	42.60	15.10	3.53	1375
	Average, -	18.74	7.46	2.95	41.55	24.47	4.83	1490
1133	Corn stover, -	18.07	4.56	2.20	41.60	28.73	4.84	1485
1138	Corn stover, -	31.86	6.25	1.63	33.36	22.60	4.30	1225
1148	Corn stover, -	31.41	4.63	1.58	34.20	23.16	5.02	1220
1161	Corn stover, -	15.10	6.47	1.41	42.89	27.48	6.65	1485
1167	Corn stover, -	19.11	4.80	2.05	41.12	27.29	5.63	1450
1175	Corn stover, -	18.58	4.68	1.76	40.24	29.95	4.79	1470

* For description of samples, see page 19.

TABLE I.—(Continued.)

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Poten- tial En'gy.
	<i>Cured Hay and Fodders.</i>	%	%	%	%	%	%	Calor's per lb.
1199	Corn stover, - -	5.52	4.78	2.17	49.35	31.84	6.34	1690
1206	Corn stover, - -	16.64	3.91	1.50	42.71	29.02	6.22	1470
1212	Corn stover, - -	21.73	6.45	2.02	41.33	22.14	6.33	1335
	Average, - -	19.78	5.17	1.81	40.76	26.91	5.57	1430
	<i>Milling Products.</i>							
1146	Corn meal, - -	11.21	9.94	4.47	71.68	1.21	1.49	1730
1158	Corn meal, - -	11.86	8.48	4.95	72.11	.98	1.62	1730
1164	Corn meal, - -	13.24	7.71	4.89	70.79	1.83	1.54	1700
1171	Corn meal, - -	13.85	10.00	5.83	66.77	1.62	1.93	1700
1181	Corn meal, - -	14.60	8.80	4.92	67.94	2.48	1.26	1660
1186	Corn meal, - -	13.98	9.36	5.26	68.15	1.63	1.62	1695
1192	Corn meal, - -	9.29	9.80	4.70	72.70	1.81	1.70	1765
	Average, - -	12.58	9.16	5.00	70.02	1.65	1.59	1710
1135	Cob meal, - -	11.76	8.82	4.05	71.01	2.94	1.42	1715
1155	Cob meal, - -	14.26	10.29	4.34	65.50	3.60	2.01	1660
1202	Cob meal, - -	13.70	8.10	5.20	69.13	2.26	1.61	1700
1209	Cob meal, - -	14.53	8.23	4.57	69.75	1.51	1.41	1675
1214	Cob meal, - -	15.03	8.82	5.05	66.20	3.02	1.88	1665
	Average, - -	13.86	8.85	4.64	68.32	2.66	1.67	1685
1116	Wheat bran, - -	10.73	16.79	4.71	53.94	8.05	5.78	1665
1136	Wheat bran, - -	9.06	16.77	4.80	54.96	8.42	5.99	1695
1154	Wheat bran, - -	9.35	17.00	5.26	52.92	10.10	5.37	1710
1160	Wheat bran, - -	9.31	15.65	4.30	56.16	8.87	5.71	1700
1166	Wheat bran, - -	9.28	17.69	4.80	54.53	8.08	5.62	1695
1173	Wheat bran, - -	9.48	16.01	4.80	54.53	9.73	5.45	1695
1180	Wheat bran, - -	9.00	16.10	5.96	52.00	11.70	5.24	1735
1187	Wheat bran, - -	9.06	14.78	5.65	55.83	9.35	5.33	1730
1197	Wheat bran, - -	9.11	18.01	4.91	56.42	6.72	4.83	1715
1203	Wheat bran, - -	10.56	18.06	4.80	55.35	6.65	4.58	1695
1208	Wheat bran, - -	11.52	18.14	5.23	53.52	6.54	5.05	1675
	Average, - -	9.68	16.82	5.02	54.56	8.56	5.36	1700
1119	Wheat middlings, -	11.11	17.72	6.07	49.70	10.22	5.18	1700
1122	Wheat middlings, -	9.31	15.64	5.25	53.41	10.33	6.06	1700
1141	Wheat middlings, -	9.39	21.47	4.91	55.71	4.65	3.87	1730
1145	Wheat middlings, -	11.95	19.10	6.04	51.82	6.50	4.59	1695
1151	Wheat middlings, -	9.17	20.44	6.53	54.08	5.36	4.42	1760
1172	Wheat middlings, -	10.19	19.14	5.77	53.83	6.32	4.75	1720
1193	Wheat middlings, -	9.49	19.69	5.50	52.98	7.31	5.03	1720
1213	Wheat middlings, -	14.16	16.90	4.61	57.45	3.74	3.14	1645
	Average, - -	10.60	18.75	5.59	53.62	6.81	4.63	1710
1118	Linseed meal, - -	10.48	32.73	8.77	34.33	8.29	5.40	1775
1182	Linseed meal, - -	9.90	34.69	5.80	39.73	4.08	5.80	1705
1201	Linseed meal, - -	9.46	18.68	7.37	51.58	7.41	5.50	1755
	Average, - -	9.95	28.70	7.31	41.88	6.59	5.57	1745
1131	Cotton seed meal, -	7.29	42.93	9.05	27.72	6.03	6.98	1810
1134	Cotton seed meal, -	7.51	44.75	9.52	26.41	4.57	7.24	1810
1143	Cotton seed meal, -	6.97	44.48	14.00	24.84	2.78	6.93	1930
1147	Cotton seed meal, -	7.62	43.19	14.19	25.47	1.88	7.65	1910
1157	Cotton seed meal, -	16.25	42.98	14.72	15.59	2.81	7.65	1765

* For description of samples, see page 20.

TABLE 1.—(Continued.)

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Poten- tial Eng'y.
	<i>Milling Prod.--(Con.)</i>	%	%	%	%	%	%	Calor's per lb.
1165	Cotton seed meal, -	6.48	42.68	11.47	28.09	3.68	7.60	1870
1170	Cotton seed meal, -	5.37	45.66	11.76	32.23	3.26	1.72	2010
1184	Cotton seed meal, -	6.52	44.00	10.00	28.79	3.60	7.09	1845
1191	Cotton seed meal, -	5.29	42.86	13.86	27.66	2.35	7.08	1940
	Average, -	7.70	43.73	12.06	26.31	3.44	6.76	1875
1179	Pea meal, -	11.02	26.69	1.50	53.93	3.28	3.58	1625
1117	Gluten meal, -	8.44	24.16	11.90	49.21	5.32	.97	1965
1128	Gluten meal, -	8.77	17.84	9.61	55.79	7.22	.77	1930
1207	Gluten meal, -	9.60	11.81	13.92	57.73	5.69	1.25	1985
1124	Gluten meal, -	9.10	38.58	4.74	45.14	1.59	.85	1785
1140	Gluten meal, -	7.17	26.05	11.59	49.81	4.19	1.19	1980
1159	Gluten meal, -	7.74	34.14	14.97	41.10	1.29	.76	2055
1196	Gluten meal, -	7.71	36.05	13.55	40.02	1.17	.60	2025
	Average, -	8.36	26.95	11.47	48.53	3.78	.91	1960
1130	Hominy chop, -	9.64	10.79	8.21	64.33	4.45	2.58	1825
1185	Malt sprouts, -	10.21	25.09	2.04	44.10	12.31	6.25	1600
1195	Oat feed, -	6.61	17.05	8.43	60.07	4.25	3.59	1870
1204	Oat feed, -	7.55	16.93	8.37	57.00	5.98	4.17	1840
	Average, -	7.08	16.99	8.40	58.54	5.11	3.88	1855
1125	Corn and oats, -	9.92	11.20	4.39	66.89	5.26	2.34	1735
1152	Corn and oats, -	10.63	9.83	4.48	70.28	2.43	2.35	1725
	Average, -	10.28	10.51	4.43	68.59	3.84	2.35	1730
1120	Rye bran, -	11.15	15.72	2.82	63.15	3.90	3.26	1660
1200	Rye meal, -	12.43	8.97	1.72	74.11	1.49	1.28	1645
1189	Sheep feed, -	48.16	8.42	1.77	32.68	6.69	2.28	965
1139	Shorts and skim milk,	9.14	22.94	4.68	49.45	7.60	6.19	1685

TABLE 2.

Proximate Composition of Fodders and Feeding Stuffs.—Results of Analyses Herewith Reported, Calculated to Water-free Substance (Dry Matter).

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Poten- tial En'gy.
	<i>Green Fodders.</i>	%	%	%	%	%	Calor's per lb.
1218	Avena elatior, - - -	7.68	3.13	47.11	35.02	7.06	1800
1219	Avena elatior, - - -	7.42	3.12	45.90	36.17	7.39	1795
1220	Avena elatior, - - -	10.72	3.53	44.23	34.45	7.07	1810
1221	Avena elatior, - - -	13.74	3.64	42.80	32.46	7.36	1805
	Average, - - -	9.89	3.35	45.01	34.53	7.22	1805
1222	Festuca elatior, - - -	7.47	2.63	46.32	36.48	7.10	1790
1223	Festuca elatior, - - -	7.76	2.85	46.04	36.04	7.31	1790
1224	Festuca elatior, - - -	10.44	2.66	43.13	36.06	7.71	1780
1225	Festuca elatior, - - -	14.11	3.25	41.02	33.29	8.33	1785
	Average, - - -	9.94	2.85	44.13	35.47	7.61	1785
1226	Dactylis glomerata, - -	8.30	3.56	44.71	36.38	7.05	1815
1227	Dactylis glomerata, - -	7.73	3.45	45.01	36.13	7.68	1800

* For description of samples, see pages 17-20.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Poten- tial En'gy.
	<i>Green Fodders.—(Con.)</i>	%	%	%	%	%	Calor's per lb.
1228	Dactylis glomerata, - -	11.97	3.86	42.08	33.42	8.67	1795
1229	Dactylis glomerata, - -	16.80	4.45	38.64	31.23	8.88	1805
	Average, - - -	11.20	3.83	42.61	34.29	8.07	1805
1230	Phleum pratense, - - -	7.92	3.28	48.31	34.44	6.05	1825
1231	Phleum pratense, - - -	7.72	2.80	47.95	35.06	6.47	1805
1232	Phleum pratense, - - -	8.99	2.77	46.27	35.78	6.19	1810
1233	Phleum pratense, - - -	11.93	2.98	44.58	34.39	6.12	1820
	Average, - - -	9.14	2.96	46.77	34.92	6.21	1815
1234	Cow pea vines, - - -	17.11	3.76	47.50	19.95	11.68	1735
1235	Cow pea vines, - - -	19.21	3.69	44.03	20.06	13.01	1705
1236	Cow pea vines, - - -	18.83	3.07	44.17	21.02	12.91	1695
1237	Cow pea vines, - - -	17.02	3.44	48.59	19.86	11.09	1735
1238	Cow pea vines, - - -	18.94	3.28	45.23	20.22	12.33	1710
1239	Cow pea vines, - - -	19.76	3.50	42.77	20.31	13.66	1690
1240	Cow pea vines, - - -	17.24	3.62	47.21	19.91	12.02	1720
1241	Cow pea vines, - - -	16.01	3.48	45.06	22.60	12.85	1705
1242	Cow pea vines, - - -	19.88	3.61	41.06	22.53	12.92	1705
1243	Cow pea vines, - - -	18.02	3.58	42.65	22.24	13.51	1695
1244	Cow pea vines, - - -	19.17	3.55	43.80	21.40	12.08	1720
1245	Cow pea vines, - - -	18.08	3.73	44.49	21.42	12.28	1720
1246	Cow pea vines, - - -	21.73	4.17	38.50	21.92	13.68	1705
1247	Cow pea vines, - - -	21.06	4.11	37.88	23.06	13.89	1700
1248	Cow pea vines, - - -	20.02	4.63	40.44	23.06	11.85	1745
	Average, - - -	18.81	3.68	43.56	21.30	12.65	1712
	<i>Ensilage.</i>						
1115	Corn ensilage, - - -	9.63	4.20	53.17	26.06	6.94	1830
1123	Corn ensilage, - - -	7.19	2.89	50.97	33.04	5.91	1820
1142	Corn ensilage, - - -	6.06	2.90	57.69	27.04	6.31	1810
1183	Corn ensilage, - - -	10.69	4.27	46.48	32.48	6.08	1850
1190	Corn ensilage, - - -	6.75	4.16	55.03	28.39	5.67	1855
	Average, - - -	8.06	3.68	52.68	29.40	6.18	1835
	<i>Field Cured Hay.</i>						
1249	Hungarian grass, - -	8.09	3.41	53.00	29.32	6.18	1825
1250	Hungarian grass, - -	9.82	3.22	50.65	29.74	6.57	1815
1251	Hungarian grass, - -	8.48	2.96	50.79	30.40	7.37	1795
1252	Hungarian grass, - -	9.26	2.98	49.73	30.14	7.89	1785
1253	Hungarian grass, - -	8.07	2.73	51.40	30.95	6.85	1795
1254	Hungarian grass, - -	10.16	3.35	49.01	30.31	7.17	1810
1255	Hungarian grass, - -	14.21	3.71	44.78	29.60	7.70	1805
1256	Hungarian grass, - -	8.48	3.21	50.20	30.40	7.71	1790
1257	Hungarian grass, - -	8.66	2.76	49.12	31.64	7.82	1780
1258	Hungarian grass, - -	10.92	3.13	46.29	31.71	7.95	1785
1259	Hungarian grass, - -	10.65	3.26	46.77	31.61	7.71	1795
1260	Hungarian grass, - -	11.90	3.40	45.93	31.14	7.63	1800
1261	Hungarian grass, - -	13.04	3.41	45.88	29.80	7.87	1795
	Average, - - -	10.14	3.19	48.74	30.51	7.42	1800
	<i>Cured Hay and Fodders.</i>						
1215	Mixed hay and stover, -	9.44	3.48	50.64	29.84	6.60	1820
1127	Hay, mixed, - - -	9.13	3.46	49.16	32.19	6.06	1830
1150	Hay, mixed, - - -	7.19	3.41	52.46	31.26	5.68	1835
1153	Hay, mixed, - - -	8.81	3.83	53.20	27.81	6.35	1830
1156	Hay, mixed, - - -	11.88	3.15	46.79	30.85	7.33	1800
1163	Hay, mixed, - - -	7.56	2.52	50.22	33.46	6.24	1800

* For description of samples, see pages 18 and 19.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Potential En'gy.
	<i>Cured Hay, etc.—(Con.)</i>	%	%	%	%	%	Calor's per lb.
1168	Hay, mixed, - - -	10.38	3.81	49.33	28.37	8.11	1800
1176	Hay, mixed, - - -	7.88	2.66	43.47	39.65	6.34	1805
1177	Hay, mixed, - - -	9.94	3.53	48.18	32.19	6.16	1830
1188	Hay, mixed, - - -	10.69	4.38	50.43	27.44	7.06	1835
1194	Hay, mixed, - - -	10.50	3.30	49.02	29.70	7.48	1800
1198	Hay, mixed, - - -	10.12	4.32	50.54	27.39	7.63	1820
1205	Hay, mixed, - - -	8.44	2.37	54.23	29.70	5.26	1820
1210	Hay, mixed, - - -	8.56	3.69	53.87	27.90	5.98	1835
1211	Hay, mixed, - - -	8.75	3.70	50.60	30.09	6.86	1820
1144	Hay, mixed, - - -	10.13	3.21	45.46	34.56	6.64	1815
1126	Hay, mixed, - - -	10.19	3.25	47.09	32.49	6.98	1810
1137	Hay, mixed, - - -	9.00	4.05	50.97	28.63	7.35	1820
	Average, - - -	9.36	3.45	49.71	30.80	6.68	1820
1120	Timothy and red-top hay, -	8.81	3.50	48.91	33.15	5.63	1840
1132	Timothy and red-top hay, -	6.50	3.49	53.46	31.66	4.89	1850
	Average, - - -	7.65	3.50	51.18	32.41	5.26	1845
1162	Rowen hay, - - -	16.19	4.50	44.73	27.06	7.52	1825
1169	Rowen hay, - - -	15.13	4.02	46.97	26.07	7.81	1810
1178	Rowen hay, - - -	14.94	3.57	46.36	29.25	5.88	1835
	Average, - - -	15.42	4.03	46.02	27.46	7.07	1825
1121	Oat hay, - - -	9.63	3.09	44.82	34.74	7.72	1790
1149	Oat hay, - - -	6.63	3.31	51.32	33.60	5.14	1845
1174	Oat hay, - - -	11.63	4.66	58.24	20.64	4.83	1880
	Average, - - -	9.29	3.69	51.46	29.66	5.90	1835
1133	Corn stover, - - -	5.56	2.68	50.78	35.07	5.91	1815
1138	Corn stover, - - -	9.18	2.39	48.95	33.17	6.31	1800
1148	Corn stover, - - -	6.75	2.31	49.85	33.77	7.32	1780
1161	Corn stover, - - -	7.63	1.66	50.51	32.37	7.83	1755
1167	Corn stover, - - -	5.94	2.53	50.83	33.74	6.96	1790
1175	Corn stover, - - -	5.75	2.16	49.42	36.79	5.88	1805
1199	Corn stover, - - -	5.06	2.30	52.23	33.70	6.71	1790
1206	Corn stover, - - -	4.69	1.81	51.23	34.81	7.46	1765
1212	Corn stover, - - -	8.25	2.58	52.79	28.29	8.09	1770
	Average, - - -	6.54	2.27	50.73	33.52	6.94	1785
	<i>Milling Products.</i>						
1146	Corn meal, - - -	11.19	5.04	80.73	1.36	1.68	1945
1158	Corn meal, - - -	9.63	5.62	81.80	1.11	1.84	1955
1164	Corn meal, - - -	8.88	5.64	81.59	2.11	1.78	1960
1171	Corn meal, - - -	11.63	6.77	77.48	1.88	2.24	1980
1181	Corn meal, - - -	10.31	5.76	79.55	2.90	1.48	1970
1186	Corn meal, - - -	10.88	6.12	79.21	1.90	1.89	1970
1192	Corn meal, - - -	10.81	5.18	80.14	2.00	1.87	1950
	Average, - - -	10.48	5.73	80.07	1.89	1.83	1960
1135	Cob meal, - - -	10.00	4.59	80.47	3.33	1.61	1940
1155	Cob meal, - - -	12.00	5.07	76.38	4.20	2.35	1935
1202	Cob meal, - - -	9.38	6.03	80.10	2.62	1.87	1965
1209	Cob meal, - - -	9.63	5.35	81.60	1.77	1.65	1960
1214	Cob meal, - - -	10.38	5.95	77.90	3.56	2.21	1960
	Average, - - -	10.28	5.40	79.29	3.09	1.94	1950
1116	Wheat bran, - - -	18.81	5.28	60.42	9.02	6.47	1865
1136	Wheat bran, - - -	18.44	5.28	60.43	9.26	6.59	1865
1154	Wheat bran, - - -	18.75	5.81	58.37	11.14	5.93	1885
1160	Wheat bran, - - -	17.25	4.75	61.92	9.78	6.30	1860

* For description of samples, see pages 19 and 20.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Potential En'gy.
	<i>Milling Products.—(Con.)</i>	%	%	%	%	%	Calor's per lb.
1166	Wheat bran, - - -	19.50	5.29	60.10	8.91	6.20	1870
1173	Wheat bran, - - -	17.69	5.30	60.24	10.75	6.02	1875
1180	Wheat bran, - - -	17.69	6.55	57.14	12.86	5.76	1910
1187	Wheat bran, - - -	16.25	6.22	61.38	10.29	5.86	1895
1197	Wheat bran, - - -	19.82	5.40	62.07	7.40	5.31	1890
1203	Wheat bran, - - -	20.19	5.37	61.88	7.44	5.12	1895
1208	Wheat bran, - - -	20.50	5.91	60.48	7.40	5.71	1890
	Average, - - -	18.63	5.56	60.40	9.48	5.93	1880
1119	Wheat middlings, - - -	19.94	6.83	55.90	11.50	5.83	1910
1122	Wheat middlings, - - -	17.25	5.79	58.88	11.39	6.69	1875
1141	Wheat middlings, - - -	23.69	5.42	61.48	5.14	4.27	1910
1145	Wheat middlings, - - -	21.69	6.86	58.86	7.38	5.21	1925
1151	Wheat middlings, - - -	22.50	7.19	59.54	5.90	4.87	1940
1172	Wheat middlings, - - -	21.31	6.42	59.94	7.04	5.29	1910
1193	Wheat middlings, - - -	21.75	6.08	58.53	8.08	5.56	1900
1213	Wheat middlings, - - -	19.69	5.38	66.01	4.36	3.66	1920
	Average, - - -	20.98	6.25	60.00	7.60	5.17	1910
1118	Linseed meal, - - -	36.56	9.80	38.35	9.26	6.03	1980
1182	Linseed meal, - - -	38.50	6.44	44.09	4.53	6.44	1890
1201	Linseed meal, - - -	20.63	8.14	56.97	8.19	6.07	1935
	Average, - - -	31.89	8.13	46.47	7.33	6.18	1935
1131	Cotton seed meal, - - -	46.31	9.76	29.90	6.50	7.53	1950
1134	Cotton seed meal, - - -	48.38	10.30	28.55	4.94	7.83	1960
1143	Cotton seed meal, - - -	47.81	15.05	26.70	2.99	7.45	2080
1147	Cotton seed meal, - - -	46.75	15.36	27.57	2.04	8.28	2070
1157	Cotton seed meal, - - -	51.31	17.58	18.62	3.36	9.13	2105
1165	Cotton seed meal, - - -	45.63	12.26	30.03	3.95	8.13	2000
1170	Cotton seed meal, - - -	48.25	12.43	34.06	3.44	1.82	2120
1184	Cotton seed meal, - - -	47.07	10.72	30.78	3.85	7.58	1970
1191	Cotton seed meal, - - -	45.25	14.63	29.20	2.49	8.43	2045
	Average, - - -	47.42	13.12	28.38	3.73	7.35	2035
1179	Pea meal, - - -	30.00	1.68	60.61	3.69	4.02	1825
1117	Gluten meal, - - -	26.38	13.00	53.74	5.82	1.06	2150
1128	Gluten meal, - - -	19.56	10.54	61.15	7.91	.84	2090
1207	Gluten meal, - - -	13.06	15.40	63.86	6.29	1.39	2200
1124	Gluten meal, - - -	42.44	5.21	49.66	1.75	.94	1965
1140	Gluten meal, - - -	28.06	12.48	53.65	4.52	1.29	2130
1159	Gluten meal, - - -	37.00	16.23	44.54	1.40	.83	2225
1196	Gluten meal, - - -	39.06	14.68	44.33	1.27	.66	2195
	Average, - - -	29.36	12.51	52.99	4.14	1.00	2135
1130	Hominy chop, - - -	11.94	9.09	71.19	4.92	2.86	2025
1185	Malt sprouts, - - -	27.94	2.27	49.11	13.71	6.97	1785
1195	Oat feed, - - -	18.25	9.03	64.31	4.56	3.85	2000
1204	Oat feed, - - -	18.31	9.06	61.64	6.47	4.52	1990
	Average, - - -	18.28	9.04	62.98	5.51	4.19	1995
1125	Corn and oats, - - -	12.44	4.87	74.25	5.84	2.60	1925
1152	Corn and oats, - - -	11.00	5.01	78.64	2.72	2.63	1930
	Average, - - -	11.72	4.94	76.44	4.28	2.62	1930
1129	Rye bran, - - -	17.69	3.18	71.07	4.39	3.67	1870
1200	Rye meal, - - -	10.25	1.97	84.61	1.70	1.47	1880
1189	Sheep feed, - - -	16.25	3.42	63.03	12.90	4.40	1860
1139	Shorts and skim milk, -	25.25	5.15	54.42	8.37	6.81	1855

* For description of samples, see pages 19-24.

FEEDING EXPERIMENT WITH SHEEP.

BY CHAS. D. WOODS AND C. S. PHELPS.

The experiment was undertaken in order to observe the effects of different kinds of food upon the chemical composition of the flesh of sheep.

PLAN OF THE EXPERIMENT.

The plan consisted in selecting a number of sheep of the same breed and age, and as nearly alike as possible, and dividing them into three groups. One group was to be butchered at the beginning of the experiment and the flesh analyzed. The results of the weighings and analysis of this group would serve to indicate more or less accurately the condition of the other animals at the beginning of the experiment. The two other groups were to be fed differently, one upon a wide ration (relatively deficient in protein), the other upon a narrow ration* (relatively rich in protein). At the end of the experiment the animals were to be all butchered and as complete analysis of the flesh made as should seem advisable.

DETAILS OF THE EXPERIMENT.

Early in December, 1892, 12 grade Shropshire wethers of the preceding spring were purchased for the experiment. They were bred and raised in Vermont, and had been at pasture very nearly up to the time of purchase by the Station. They were in average condition as regards fatness. Soon after the animals were received at the Station they were divided into two lots of about uniform total weights. The sheep were all closely sheared Dec. 10. December 29 one animal was selected from each lot for immediate slaughter and analysis. Each of the ten remaining animals was placed in a pen by itself, though the grouping was kept up as before. At this date (Dec. 29) five animals (Nos. 3-7) in the group which were intended to be fed the "wide

* In order that a ration may be complete there must be enough digestible protein in the food to build new tissues (bone, muscle, wool, etc.) and repair the wastes of the body, and sufficient digestible fat and carbohydrates to furnish heat and muscular energy. If the sum of the digestible carbohydrates and two and a half times the digestible fat of a ration is divided by the amount of digestible protein in the ration, the quotient gives what is called the nutritive ratio. If the quantities of digestible fat and carbohydrates are large relative to the protein this number will be large, and the ration is called a "wide ration;" if the quantities of digestible fat and carbohydrates are relatively small the quotient is a small number and the ration is a "narrow" one. A ration where the nutritive ratio is much more than 1 : 6 is called a "wide ration;" if much less, it is called a "narrow ration." "Wide rations" are more common among American feeders than are "narrow" ones.

ration" weighed 362 pounds, and the five animals (Nos. 8-12) which were to be fed the "narrow" ration weighed 361 pounds. The first week after the separation of the animals there were quite marked differences in their apparent growth. One animal in each group gained, but on the whole the animals lost in weight so that on January 5th, when the feeding experiment actually began, the animals of the wide ration group (Nos. 3-7) weighed 356½ pounds, and those of the narrow ration group (Nos. 8-12) weighed 355 pounds.

The two animals (Nos. 1 and 2) which had been selected for slaughter at the commencement of the experiment were kept together until Jan. 5, when they were butchered. In the meantime they had also changed in weight. December 29 No. 1 weighed 73 pounds, and on Jan. 5th, when butchered, it weighed 74 pounds, and No. 2, which weighed 72 pounds on Dec. 29, had decreased in weight to 69 pounds on Jan. 5.

By this arrangement the group slaughtered at the beginning of the actual experiment consisted of two animals, while the two groups which were fed had five each. It would have been more satisfactory to slaughter and analyze five for the measure of the amount and composition of the flesh at the beginning, but the pressure of work at the time made so large a number of weighings and analyses difficult, and furthermore the whole experiment was regarded as preliminary to more extended series of trials and one of its objects was to get experience; hence the smaller number was taken. The figures in the following tabulation indicate that the average weights of the animals of the three groups at the beginning of the actual experiment, January 5th, were nearly the same.

Average Weights of Sheep of Different Groups at Beginning and End of Preliminary Period of One Week.

	SLAUGHTERED.	FED.	
	Two Sheep. Nos. 1 and 2.	Wide Ration. Five Sheep. Nos. 3-7.	Narrow Ration. Five Sheep. Nos. 8-12.
December 29th,	72.5 lbs.	72.4 lbs.	72.2 lbs.
January 5th,	71.5 lbs.	71.3 lbs.	71.0 lbs.

The actual feeding experiment continued until March 29th, eighty-four days.

It should be explained that as the animals were kept in separate pens they were more or less restive. One was very much so, as stated beyond, and it seems probable that with this animal at any rate, the result of the experiment was affected by the nervous condition of the animal.

KINDS AND AMOUNTS OF FOOD.

The animals in the wide ration group, Nos. 3 to 7, were fed a ration of hay, turnips and corn meal. Those of the narrow ration group, Nos. 8 to 12, were fed rowen hay with a grain mixture of linseed meal, pea meal, wheat bran and corn meal. The rations fed each animal are shown in table 3. In each group the grain ration at the end of five weeks was increased by a half pound per animal. The total weight of feed, exclusive of the turnips, was the same in each group, 4 pounds per day per animal for the first five weeks and $4\frac{1}{2}$ pounds per day per animal for the remaining eight weeks.

TABLE 3.

Kinds and Amounts of Food Furnished Each Animal in Sheep Feeding Experiment of 1893.

KIND OF FOOD.	Fed from Jan. 5 to Feb. 9, inclusive (36 days).		Fed from Feb. 10 to March 29, inclusive (48 days).		Total fed from Jan. 5 to March 29, in- clusive (84 days).
	Each day.	Total in 36 days.	Each day.	Total in 48 days.	
<i>Sheep Nos. 3-7.—Wide Ration.</i>					
Oz.	Lbs.	Oz.	Lbs.	Lbs.	
Corn meal, - - - - -	16	36	24	72	108
Hay, - - - - -	32	72	32	96	168
Turnips, - - - - -	24	54	24	72	126
	72	162	80	240	402
<i>Sheep Nos. 8-12.—Narrow Ration.</i>					
Linseed meal, - - - - -	2	4.5	4	12	16.5
Pea meal, - - - - -	6	13.5	12	36	49.5
Wheat bran, - - - - -	4	9	4	12	21
Corn meal, - - - - -	4	9	4	12	21
Rowen hay, - - - - -	32	72	32	96	168
	48	108	56	168	276

PERCENTAGE COMPOSITION OF FEEDING STUFFS USED.

Samples of the grain and hay fed in the experiment were taken from time to time, and from these samples smaller sub-samples were obtained at the end of the experiment for the purpose of analysis. The uneaten residues of food of each animal were carefully collected each day and weighed. The uneaten residues of each group were kept by themselves, and at the end of the experiment samples of each were taken for analysis. The percentage composition of the feeding stuffs and of the uneaten residues are shown in table 4, which follows.

TABLE 4.

*Percentage Composition of Feeding Stuffs Used and of Uneaten Residues in Sheep Feeding Experiment of 1893.**

Lab. No.	KIND OF FEEDING STUFF.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.
		%	%	%	%	%	%
1182	Linseed meal, - - -	9.90	34.69	5.80	39.73	4.08	5.80
1179	Pea meal, - - -	11.02	26.69	1.50	53.93	3.28	3.58
1180	Wheat bran, - - -	9.00	16.10	5.96	52.00	11.70	5.24
1181	Corn meal, - - -	14.60	8.80	4.92	67.94	2.48	1.26
1177	Hay, - - -	12.16	8.73	3.10	42.32	28.28	5.41
1178	Rowen hay, - - -	13.73	12.89	3.08	39.99	25.24	5.07
	Turnips,† - - -	89.10	1.10	.30	7.30	1.20	1.00
	<i>Uneaten Residues.</i>						
1217	From wide ration, - -	59.89	4.69	1.31	19.13	12.26	2.72
1216	From narrow ration, - -	61.20	7.96	1.05	17.44	9.27	3.08

* For composition calculated on water-free basis, see pages 25-27, this Report.

† Not analyzed. Averages of four analyses of New England grown ruta-bagas.

The amount of digestible nutrients was calculated by using the following factors (digestion co-efficients):

	Protein.	Fat.	CARBOHYDRATES.	
			Nitrogen-Free Extract.	Fiber.
	%	%	%	%
Linseed meal, - - -	90†	94†	96†	93†
Pea meal, - - -	83*	54*	94*	26*
Wheat Bran, - - -	78*	73*	66*	33†
Corn meal, - - -	76*	92*	87*	58†
Hay (good quality), - - -	54*	54*	63*	55*
Rowen hay, - - -	62†	46†	67†	64†
Turnips, - - -	84*	77*	95*	80*

* From American digestion experiments.

† From German digestion experiments.

Table 5 gives the rations fed and the total and digestible nutrients in the food. In the case of the wide ration the turnips are not included in this table. The sheep differed very much in the way in which they ate turnips. Only one or two of the animals ate them very well, the others eating only a small part of the quantity fed. Each day the turnips uneaten were weighed so that at the end it was possible to tell exactly what weight of turnips was eaten by each animal. These weights will be found in table 6 with the other details of the experiment.

TABLE 5.

Rations Fed. Total Nutrients and Digestible Nutrients in Rations Used in Sheep Feeding Experiment of 1893.

KIND OF FOOD.	Total Weight Fed.	TOTAL NUTRIENTS IN FOOD.				DIGESTIBLE NUTRIENTS.		
		Protein.	Fat.	Nitrogen-free ext.	Fiber.	Protein.	Fat.	Carbo-hydrates*
<i>Sheep 3-7.—Wide Ration.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal, - - -	108.0	9.5	5.3	73.3	2.7	11.2	4.9	65.3
Hay, - - -	168.0	14.7	5.2	71.1	47.5	7.9	2.8	70.9
Turnips,† - - -	—	—	—	—	—	—	—	—
Total in corn meal and hay for 84 days, - -	276.0	24.2	10.5	144.4	50.2	19.1	7.7	136.2
<i>Sheep 8-12.—Narrow Ration.</i>								
Linseed meal, - -	16.5	5.7	1.0	6.5	.7	5.1	.9	6.9
Pea meal, - - -	49.5	13.2	.7	26.7	1.6	11.0	.4	25.5
Wheat bran, - - -	21.0	3.4	1.2	10.8	2.5	2.7	.9	8.0
Corn meal, - - -	21.0	1.8	1.0	14.2	.5	1.4	.9	12.6
Rowen hay, - - -	168.0	21.6	5.2	67.0	42.4	13.3	2.4	72.0
Total fed, - - -	276.0	45.7	9.1	125.2	47.7	33.5	5.5	125.0

* The carbohydrates include the digestible fiber and nitrogen-free extract.

† See under each animal in table 6, which follows.

Table 6 shows the total and digestible nutrients actually eaten by each animal through the whole period, and also the averages for each day. The total nutrients and the digestible nutrients furnished in grain and hay are taken from table 5. The total and digestible nutrients in the uneaten residue of grain and hay are subtracted from these weights in the case of each animal. The remainders show the total and digestible nutrients furnished by grain and hay which were actually eaten. In the case of the wide ration group, Nos. 3-7, varying quantities of turnips were

eaten, and the total and digestible nutrients in the turnips eaten have been added to those of the grain and hay actually eaten. This sum gives the total eaten in the eighty-four days that the experiment lasted. Dividing the totals by eighty-four gives the averages per day.

The uneaten residues consisted of the coarser and less digestible portions of the hay, together with some grain. The grain would be more digestible than the hay, but the rejected portions of the hay were much less digestible than the whole hay, consequently it was thought that it would not be far from the truth to assume the same digestion co-efficients for the uneaten residues as for the hay used in the experiments.

Of course the estimates of amounts of digestible nutrients, which are based upon averages of experiments elsewhere, are merely estimates and must be taken for what they are worth. In experiments now being made (winter of 1893-4) the digestibility of the feeding stuffs is being tested by direct experiments with sheep.

Since the digestion co-efficients are estimated rather than actually determined, the error introduced in estimating the digestibility of the uneaten residues is less significant.

Table 7, on page 36, summarizes the total and digestible nutrients eaten by the sheep in this experiment. Wolff's (German) standard for fattening sheep calls for a ration, per 100 pounds live weight, of .30 pounds of digestible protein and sufficient digestible fat and carbohydrates to make the total energy (fuel value) equal to 3,520 calories, with a nutritive ratio of 1 to 5.5. The average of 11 experiments with 122 animals, conducted in experiment stations in five states in the United States, gives a ration, per 100 pounds of live weight, of .27 of a pound of digestible protein with sufficient digestible fat and carbohydrates to furnish 3,560 calories of energy with a nutritive ratio of 1 to 6.1. The total energy (fuel value) of each of the rations in the experiments here reported upon differs but little from either of the above. In the case of the wide ration the protein is considerably below the standard and the narrow ration is very much above the average as found in other sheep feeding experiments. It will be noticed that the narrow ration is narrower than the average of the American rations above cited, and that in the case of the wide ration, it is a good deal wider.

TABLE 6.

Estimated Total and Digestible Nutrients in Food Eaten by Each Animal in Sheep Feeding Experiment of 1893.

	TOTAL NUTRIENTS.				DIGESTIBLE NUTRIENTS.		
	Protein.	Fat.	Nit.-free Ext.	Fiber.	Protein.	Fat.	* Carbohy- drates.
WIDE RATION.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
<i>Sheep No. 3.</i>							
Furnished in grain and hay,	24.2	10.5	144.4	50.2	19.1	7.7	136.2
Uneaten residue of grain and hay (32.3 lbs.), -	1.5	.4	6.2	4.0	.8	.2	6.1
Eaten:—							
In grain and hay, -	22.7	10.1	138.2	46.2	18.3	7.5	130.1
In turnips (67.6 lbs.), -	.7	.2	4.9	.8	.6	.2	1.2
Total eaten in 84 days, -	23.4	10.3	143.1	47.0	18.9	7.7	131.3
Average per day, -	.279	.123	1.704	.560	.225	.092	1.563
<i>Sheep No. 4.</i>							
Furnished in grain and hay,	24.2	10.5	144.4	50.2	19.1	7.7	136.2
Uneaten residue of grain and hay (7.3 lbs.), -	.3	.1	1.4	.9	.2	.1	1.4
Eaten:—							
In grain and hay, -	23.9	10.4	143.0	49.3	18.9	7.6	134.8
In turnips (78.7 lbs.), -	.8	.2	5.7	.2	.6	.2	5.6
Total eaten in 84 days, -	24.7	10.6	148.7	49.5	19.5	7.8	140.4
Average per day, -	.299	.126	1.770	.589	.232	.093	1.671
<i>Sheep No. 5.</i>							
Furnished in grain and hay,	24.2	10.5	144.4	50.2	19.1	7.7	136.2
Uneaten residue of grain and hay (51.1 lbs.), -	2.4	.7	9.8	6.3	1.3	.4	9.6
Eaten:—							
In grain and hay, -	21.8	9.8	134.6	43.9	17.8	7.3	126.6
In turnips (23 lbs.), -	.2	—	1.7	.2	.2	—	1.6
Total eaten in 84 days, -	22.0	9.8	136.3	44.1	18.0	7.3	128.2
Average per day, -	.262	.117	1.623	.525	.214	.087	1.526
<i>Sheep No. 6.</i>							
Furnished in grain and hay,	24.2	10.5	144.4	50.2	19.1	7.7	136.2
Uneaten residue of grain and hay (32.5 lbs.), -	1.5	.4	6.2	4.0	.8	.2	6.1
Eaten:—							
In grain and hay, -	22.7	10.1	138.2	46.2	18.3	7.5	130.1
In turnips (23.1 lbs.), -	.2	—	1.7	.2	.2	—	1.6
Total eaten in 84 days, -	22.9	10.1	139.9	46.4	18.5	7.5	131.7
Average per day, -	.273	.120	1.665	.552	.220	.089	1.563

* The carbohydrates include both the digestible fiber and nitrogen-free extract.

TABLE 6.—(Continued.)

	TOTAL NUTRIENTS.				DIGESTIBLE NUTRIENTS.		
	Protein.	Fat.	Nit.-free Ext.	Fiber.	Protein.	Fat.	* Carbohy- drates.
WIDE RATION.—(Con.) <i>Sheep No. 7.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Furnished in grain and hay, Uneaten residue of grain and hay (26.1 lbs.), -	24.2	10.5	144.4	50.2	19.1	7.7	136.2
Eaten:—	1.2	.3	5.0	3.2	.7	.3	4.9
In grain and hay, -	23.0	10.2	139.4	47.0	18.4	7.4	131.3
In turnips (124.8 lbs.), -	1.4	.4	9.1	1.5	1.2	.3	9.8
Total eaten in 84 days, -	24.4	10.6	148.5	48.5	19.6	7.7	141.1
Average per day, -	.290	.126	1.768	.577	.233	.092	1.680
NARROW RATION. <i>Sheep No. 8.</i>							
Furnished in grain and hay, Uneaten residue of grain and hay (34.3 lbs.), -	45.7	9.1	125.2	47.7	33.5	5.5	125.0
	2.7	.4	6.0	3.2	1.7	.2	6.1
Total eaten in 84 days, -	43.0	8.7	119.2	44.5	31.8	5.3	118.9
Average per day, -	.512	.104	1.419	.530	.379	.063	1.415
<i>Sheep No. 9.</i>							
Furnished in grain and hay, Uneaten residue of grain and hay (18.3 lbs.), -	45.7	9.1	125.2	47.7	33.5	5.5	125.0
	1.5	.2	3.2	1.7	.9	.1	3.2
Total eaten in 84 days, -	44.2	8.9	122.0	46.0	32.6	5.4	121.8
Average per day, -	.526	.106	1.452	.548	.388	.064	1.450
<i>Sheep No. 10.</i>							
Furnished in grain and hay, Uneaten residue of grain and hay (0.4 lbs.), -	45.7	9.1	125.2	47.7	33.5	5.5	125.0
	.1	—	.2	—	—	—	.1
Total eaten in 84 days, -	45.6	9.1	125.0	47.7	33.5	5.5	124.9
Average per day, -	.543	.108	1.488	.568	.399	.065	1.487
<i>Sheep No. 11.</i>							
Furnished in grain and hay, Uneaten residue of grain and hay (26.1 lbs.), -	45.7	9.1	125.2	47.7	33.5	5.5	125.0
	2.0	.3	4.5	2.4	1.2	.1	4.5
Total eaten in 84 days, -	43.7	8.8	120.7	45.3	32.3	5.4	120.5
Average per day, -	.520	.105	1.437	.539	.385	.064	1.435
<i>Sheep No. 12.</i>							
Furnished in grain and hay, Uneaten residue of grain and hay (2.2 lbs.), -	45.7	9.1	125.2	47.7	33.5	5.5	125.0
	.1	—	.4	.2	.1	—	.4
Total eaten in 84 days, -	45.6	9.1	124.8	47.5	33.4	5.5	124.6
Average per day, -	.543	.108	1.486	.566	.398	.065	1.484

* The carbohydrates include both the digestible fiber and nitrogen-free extract

TABLE 7.

Average of Total and Digestible Nutrients Eaten Daily by Each Animal in Sheep Feeding Experiment of 1893. Estimated per 100 Pounds Live Weight. Summary.

SHEEP NUMBER.	TOTAL NUTRIENTS EATEN.					DIGESTIBLE NUTRIENTS.				
	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Fuel Value of Total Nutrients.	Protein.	Fat.	Carbohydrates*	Nutritive Ratio.	Fuel Value of Digest. Nts.
<i>Wide Ration.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
No. 3, -	.279	.123	1.704	.560	—	.225	.092	1.563	—	—
No. 4, -	.299	.126	1.770	.589	—	.232	.093	1.671	—	—
No. 5, -	.262	.117	1.623	.525	—	.214	.087	1.526	—	—
No. 6, -	.273	.120	1.665	.552	—	.220	.089	1.568	—	—
No. 7, -	.290	.126	1.768	.577	—	.233	.092	1.680	—	—
Average, 3-7,	.28	.12	1.71	.56	5250	.22	.09	1.60	8.2	3760
<i>Narrow Rat'n.</i>										
No. 8, -	.512	.104	1.419	.530	—	.379	.063	1.415	—	—
No. 9, -	.526	.106	1.452	.548	—	.388	.064	1.450	—	—
No. 10, -	.543	.108	1.488	.568	—	.399	.065	1.487	—	—
No. 11, -	.520	.105	1.437	.539	—	.385	.064	1.435	—	—
No. 12, -	.543	.108	1.486	.566	—	.398	.065	1.484	—	—
Average, 8-12,	.53	.11	1.46	.55	5190	.39	.06	1.45	4.1	3680
<i>Stand'rd R'tns per 100 lbs. Live Weight.</i>										
German, -	—	—	—	—	—	.30	.05	1.52	5.5	3520
American, -	—	—	—	—	—	.27	.09	1.44	6.1	3560

* Carbohydrates include both fiber and nitrogen-free extract.

RESULTS OF THE EXPERIMENTS.

At the end of the experiment March 29th, the animals were all sheared and the weight of the wool was taken. On March 30th the animals were all butchered, weighed and the meat was sent to the laboratory at Middletown for analysis.

The statistics at the time of butchering are given in table 8, on the opposite page, together with the weights at the beginning of the experiment. Animals 1 and 2 had been butchered January 5th. From the weights of the animals at the beginning and at the end of the experiment it will be seen that there was an increase in live weight, exclusive of the increase in weight due to growth of wool, varying from 14 to 31½ pounds per animal, that the average of the wide ration

group was an increase of 20.8 pounds in live weight and of the narrow ration group there was an increase of 24.3 pounds per animal. If the weights of the fleece grown during the experiment are added to the above weights, there was an average increase of 23 pounds per animal in the wide ration group and of 26½ pounds per animal in the narrow ration group.

TABLE 8.

Sheep Feeding Experiment, 1893. Statistics of Animals. All Preceding Spring Wethers.

SHEEP No.	LIVE WEIGHT.			Dressed Weight.	WEIGHT OF ORGANS, ETC.					Wool Sheared Before Taking Live Wgts.	
	At beginning of Expt. Jan. 5.	At end of Expt. March 30.	Increase in 3 Months.		Lungs.	Liver.	Heart & Casing.	Kidneys.	Intestinal Fat.		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
1	74.0	—	—	31.0	.55	1.08	.45	.22	—	—	
2	69.0	—	—	30.0	.60	1.01	.50	.20	—	—	
Average,	71.5	—	—	30.5	.58	1.05	.47	.21	—	—	
Fed on wide ration.	3	66.5	85.0	18.5	42.1	.91	1.59	.56	.22	1.41	2.50
	4	68.0	98.0	30.0	42.5	1.09	1.72	.56	.19	1.00	2.16
	5	71.5	86.5	15.0	41.8	.94	1.28	.56	.19	1.44	2.28
	6	73.0	87.0	14.0	44.2	.84	1.38	.53	.20	1.28	1.81
	7	77.5	103.5	26.0	50.5	1.00	1.50	.59	.19	1.91	2.00
	Avg.	71.3	92.1	20.8	44.2	.96	1.49	.56	.20	1.41	2.15
Fed on narrow ration.	8	66.5	85.5	19.0	44.7	.75	1.38	.53	.20	1.13	2.00
	9	66.0	87.5	21.5	42.5	1.00	1.56	.53	.20	.47*	1.75*
	10	72.0	103.5	31.5	49.0	1.03	1.72	.59	.29	1.28	1.94
	11	73.5	95.5	22.0	44.5	.94	1.53	.50	.27	1.50	2.09
	12	77.5	105.0	27.5	49.8	1.19	1.69	.63	.27	1.63	2.91
	Avg.	71.1	95.4	24.3	46.1	.98	1.58	.56	.25	1.39	2.24

* Omitted from averages.

The average live weight of the animals (see table 8 above) 1 and 2, which were selected for analysis at the start, was practically the same as that of the average of each of the groups (71.3 and 71.1 pounds). The average dressed weight of 1 and 2 was 30.5 pounds. The average dressed weight of the

wide ration group was 44.2 pounds and that of the narrow ration group was 46.1 pounds. If it is assumed that the animals at the start were all similar to 1 and 2, there would be an average increase of 13.7 pounds of dressed weight in the wide ration group and of 15.5 pounds in the narrow ration group.

The average weights of the lungs were practically the same in the wide ration group as in the narrow ration group, but it will be noticed that the lungs weighed nearly twice as much in the animals butchered at the end of the experiment as in those butchered at the beginning.

There was also a decided increase in the weight of the liver in both groups over that of the sheep butchered at the start. The average weight of the livers in 1 and 2 was 1.05 pounds, and in the wide and narrow ration groups 1.49 pounds and 1.58 pounds respectively.

There was also an increase in the weight of the heart and casing. The heart of 1 and 2 weighing .47 pounds and the wide and narrow ration groups each averaging .56 pounds

The weights of the kidneys in the two animals butchered at the beginning and in those of the wide ration group at the end were practically the same. In the narrow ration group there was an average increase of .05 pounds or one-fourth of the entire weight of the kidneys. One important function of the kidneys is to excrete the nitrogenous portions of the food in the form of urea and other compounds. The wide ration group had a small quantity of protein (nitrogenous substance) in the ration and hence had a small amount of nitrogen to eliminate. The narrow ration group had an excess of protein and hence much nitrogen to dispose of. In this case, as was to be expected, the organ that was called upon to perform the extra work was developed so as to adapt itself to the demands upon it.

The animals slaughtered at the beginning of the experiment had practically no fat upon the intestines. The animals of each group (with the exception of No. 9) gave an average development of about 1.4 pounds intestinal fat, there being, with the exception noted, very little difference in the averages of the two groups.

Sheep No. 9 is omitted from this average and from those of the two following tables as the results are so very different from those of the other four animals of the same group. This sheep never became reconciled to the solitary confinement

of the experiment and was always uneasy. Several times he succeeded in jumping out of the pen. To the nervous condition of the animal and his active habit, the difference found in the analytical results can doubtless be attributed. The principal difference between the composition of the flesh of No. 9 and that of the others of the narrow ration group is in the weight of fat developed, both in the flesh and in the portions of the body about the kidneys and intestines, where clear fat usually accumulates in greater or less quantity.

With the exception of sheep No. 9 there is very little difference in the growth of wool. On the whole the animals of the narrow ration group grew a little better fleece than the others did. The weights as given are for the wool as sheared and without cleansing.

TABLE 9.

Summary of Rations Fed and Averages of Digestible Nutrients Eaten and Gain in Live and Dressed Weights Per Animal.

ALL AVERAGES PER ANIMAL.	RATIONS FED.			DIGESTIBLE NUTRIENTS IN FOOD ACTUALLY EATEN.				INCREASE.	
	Grain.	Hay.	Roots.	Total Organic Matter.	Protein.	Fat.	Carbohydrates.	Live Wgt., Including Fleece.	Dressed Wgt.
<i>Whole period of 84 days.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wide ration, - -	108	168	126*	160.9	18.9	7.6	134.4	23.0	13.7
Narrow ration, - -	108	168	—	159.5	32.7	5.0	121.8	26.5	15.6
<i>To produce a gain of 1 lb. live weight.</i>									
Wide ration, - -	4.7	7.3	5.5†	6.99	.82	.33	5.84	1.0	.6
Narrow ration, - -	4.1	6.3	—	6.02	1.23	.19	4.60	1.0	.6
<i>To produce a gain of 1 lb. dressed weight.</i>									
Wide ration, - -	8.1	12.3	9.2‡	11.74	1.38	.55	9.81	1.7	1.0
Narrow ration, - -	6.9	10.8	—	10.23	2.10	.32	7.81	1.7	1.0

* 36 pounds eaten. † 1.6 pounds eaten. ‡ 2.6 pounds eaten.

Table 9 above gives a summary of the grain and hay actually fed per animal in this experiment, together with the digestible nutrients actually eaten and the gain in live and dressed weights. There are also given the weights of food and

digestible nutrients which were eaten on the average per animal to produce a gain of one pound in the live and dressed weights.

CHEMICAL COMPOSITION OF THE FLESH.

As stated above, analyses were made of the flesh of the animals. In each case the right side was used for analysis. The flesh of the entire side was carefully separated from the bones and then finely cut in a sausage machine. After thoroughly mixing, a small sample was selected and prepared for analysis in the usual way.* The results of the analysis calculated both on water-free (dry matter) and fresh substance, (flesh) are given in the table (10) which follows. As explained on p. 38, sheep No. 9 is omitted from the averages.

TABLE 10.

Percentage Composition of Flesh, Edible Portion, of Animals in Sheep Feeding Experiment of 1893.

Lab. No.		CALCULATED ON WATER-FREE BASIS.			CALCULATED TO WATER CONTENT OF FLESH.			
		Pro- tein.	Fat.	Ash.	Water.	Pro- tein.	Fat.	Ash.
	<i>At Beginning of Exp't.</i>	%	%	%	%	%	%	%
364	Sheep No. 1, - -	44.50	52.90	2.60	59.95	17.83	21.18	1.04
365	Sheep No. 2, - -	38.27	59.40	2.33	56.77	16.54	25.68	1.01
	Average 1 and 2, -	41.39	56.15	2.46	58.36	17.19	23.43	1.02
	<i>Wide Ration.</i>							
366	Sheep No. 3, - -	38.20	59.66	2.14	58.13	16.00	24.97	.90
368	Sheep No. 4, - -	35.97	62.06	1.97	58.07	15.07	26.03	.83
370	Sheep No. 5, - -	36.22	61.70	1.99	58.24	15.13	25.81	.82
372	Sheep No. 6, - -	32.15	66.12	1.73	57.23	13.75	28.28	.74
374	Sheep No. 7, - -	32.03	66.26	1.71	55.07	14.39	29.77	.77
	Average 3-7, - -	34.91	63.18	1.91	57.35	14.87	26.97	.81
	<i>Narrow Ration.</i>							
367	Sheep No. 8, - -	34.31	63.89	1.80	56.35	14.96	27.91	.78
369	Sheep No. 9,† - -	53.84	43.33	2.83	68.27	17.08	13.76	.89
371	Sheep No. 10, - -	38.63	59.29	2.08	59.63	15.59	23.94	.84
373	Sheep No. 11, - -	38.54	59.38	2.08	61.18	14.96	23.05	.81
375	Sheep No. 12, - -	34.65	63.55	1.80	58.21	14.50	26.55	.74
	Average 8, 10-12 (4),	36.54	61.52	1.94	58.84	15.00	25.37	.79

† Omitted from averages.

In table 11 there are given the weights of the nutrients, etc., in the flesh of each animal of the experiment. The figures in the last five columns were obtained by multiplying the weight of flesh (edible portion) by the percentage composition of the

* For methods of analysis of meats, see Report of this Station for 1891, pp. 47-49.

animals as given in table 10. Sheep No. 9 was omitted from the averages for reasons given on page 38.

TABLE 11.

Weights of Flesh, Refuse, and Nutrients in Flesh of Animals in Sheep Feeding Experiment of 1893.

	Live Weight.	Dressed W'gt, without Kidneys & Hoofs.	Refuse (Bone).	Edible Portion (Flesh).	IN EDIBLE PORTION (FLESH).				
					Water.	Water-free Substance.	Water-free Sub.		
							Protein.	Fat.	Ash.
<i>Beginning of Exp't.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Sheep No. 1, -	74.0	29.49	6.36	23.13	13.85	9.28	4.14	4.90	.24
Sheep No. 2, -	69.0	28.80	5.41	23.39	13.27	10.12	3.87	6.01	.24
Av. 1 and 2, -	71.5	29.15	5.89	23.26	13.56	9.70	4.01	5.45	.24
<i>Wide Ration.</i>									
Sheep No. 3, -	85.0	40.99	7.07	33.92	19.72	14.20	5.43	8.47	.30
Sheep No. 4, -	98.5	41.25	8.99	32.26	18.74	13.52	4.86	8.39	.27
Sheep No. 5, -	86.5	40.55	7.63	32.92	19.18	13.74	4.97	8.50	.27
Sheep No. 6, -	87.0	43.08	6.31	36.77	21.04	15.73	5.06	10.40	.27
Sheep No. 7, -	103.5	48.96	7.74	41.22	22.69	18.53	5.93	12.28	.32
Av. 3-7, -	92.1	42.97	7.55	35.42	20.28	15.14	5.25	9.60	.29
<i>Narrow Ration.</i>									
Sheep No. 8, -	85.5	43.73	7.04	36.69	20.66	16.03	5.50	10.24	.29
Sheep No. 9,* -	87.5	41.29	7.85	33.44	22.82	10.62	5.72	4.60	.30
Sheep No. 10, -	103.5	47.72	8.16	39.56	23.59	15.97	6.17	9.47	.33
Sheep No. 11, -	95.5	43.01	8.69	34.32	21.00	13.32	5.12	7.92	.28
Sheep No. 12, -	105.0	48.32	8.35	39.97	23.27	16.70	5.79	10.61	.30
Av. 8, 10-12, -	97.4	45.70	8.06	37.64	22.13	15.51	5.65	9.56	.30

* Omitted from average.

The following table points out the difference in the composition of the flesh:

Changes in Composition of Flesh, with Different Rations. (Increase, +. Decrease, -).

	IN 100 LBS. WATER-FREE SUBSTANCE OF FLESH.			IN 100 LBS. OF FLESH.			
	Protein.	Fat.	Ash.	Wa	Protein.	Fat.	Ash.
<i>Increase over beginning of Experiment.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wide ration, - - -	-6.4	+7.0	-0.6	-1.0	-2.3	+3.5	-0.2
Narrow ration, - - -	-4.8	+5.4	-0.6	+0.5	-2.2	+1.9	-0.2
Increase of narrow over wide ration, - - -	+1.6	-1.6	+0.0	+1.5	+0.1	-1.6	+0.0

In the dry matter (water-free substance) of flesh there was in each group an increase in the fat and a corresponding decrease in protein and ash. These differences were greater in the wide ration group, as the last line of the table points out.

The chief differences in composition between the different groups when calculated to fresh substance of flesh, are still due to the fat. One of the facts brought out very early in our study of the composition of animal foods was that water and fat to a very great extent replace each other. This is strikingly shown in the composition of the flesh of the animals of the wide and narrow rations. The protein is nearly the same in each, while the flesh of the narrow ration animals contains 1.5 pounds per 100 more water, and 1.6 pounds per 100 less fat than that of the wide ration group.

The average differences in composition are pointed out in the following table:

Changes in Weights of Nutrients, with Different Rations.

	Edible Portion (Flesh).	IN EDIBLE PORTION (Flesh).				
		Water.	Water-free sub- stance.	In Water-free Sub- stance.		
				Protein.	Fat.	Ash.
<i>Increase over beginning of Exp't.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wide ration group, average of 5 animals, - - - - -	12.12	6.72	5.44	1.24	4.15	.05
Narrow ration group, average of 4 animals, - - - - -	14.38	8.57	5.81	1.64	4.11	.06
Increase of narrow ration over wide ration group, * - - - -	2.22	1.85	.37	.40	-.04	.01

The gain in the weight of flesh was enough greater in the animals of the narrow ration group to very nearly compensate for the lower percentage of fat, so that the weight of fat was nearly as great in this group as in the wide ration group. The increase in dry matter, water and protein was to have been expected from the percentage composition.

The work is being continued during the present winter (1893-4) and practical conclusions are reserved.

BACTERIA IN THE DAIRY.*

BY H. W. CONN.

V. THE RIPENING OF CREAM BY ARTIFICIAL CULTURES OF BACTERIA.

Experiments upon artificial ripening of cream are not new. It was Professor Storch of Copenhagen (*Milchzeitung*, 1890, p. 304) who first called attention of bacteriologists to the subject by using artificial cultures of bacteria for the purpose and showing that while some species produced an excellent aroma in the butter, others produced butter of very inferior quality. Others have followed this lead, especially Weigmann (*Landw. Woch. Schleswig-Holstein*, 1890, pp. 551 and 869) and Adametz and Wilckens (*Landw. Jahrb.*, 1892, p. 131) and artificial cultures for this purpose have for some time been furnished to creameries in Europe and to a slight extent in this country. The exact effect upon butter of the numerous species of bacteria which are liable to occur in cream is too little known from these experiments. Storch and Weigmann were endeavoring to find a proper species for the purpose and have given us too few details concerning other species. Adametz and Wilckens gave more detailed accounts of several species but there is still little known of the effect of the great bulk of milk bacteria.

In this country very little knowledge of these general facts is found among dairymen. For the purpose of giving a wide information upon the subject, the Office of Experiment Stations at Washington requested me to prepare an exhibit illustrating some of these facts for the Columbian Exposition. In preparing for this exhibition a large number of experiments have been performed upon the ripening of cream by the aid of artificial cultures of different species of bacteria. These experiments are somewhat novel in their character and unlike any that have been

*During the past six years investigations on the Bacteria of Milk have been conducted in behalf of the Station by H. W. Conn, Professor of Biology in Wesleyan University. Some of the results have been given in the publications of the Station, as follows: *Bacteria in Milk, Cream, and Butter*, Bulletin 4, and Annual Report for 1889, pp. 52-67. *Ripening of Cream*, Annual Report for 1890, pp. 136-157. *A Micrococcus of Bitter Milk*, Report for 1891, pp. 158-162. *The Isolation of Rennet from Bacteria Cultures*, Report for 1892, pp. 106-126. See also *The Fermentations of Milk*, Experiment Station Bulletin No. 9 of the Office of the Experiment Station of the U. S. Department of Agriculture.

as yet carried on in any bacteriological laboratory. The results, while aimed especially at preparing a proper exhibit for the Columbian Fair, have, at the same time, been of great interest to the practice of butter making, both scientifically and practically. For this reason it is thought well to give at the present time the methods of these experiments and the general summary of the results, especially as they add considerably to our knowledge of the relation of different species of organisms to the matter of butter making.

The first object of the experiments was to find certain species of bacteria whose use in the ripening of cream would produce a marked effect upon the aroma of the butter. It was desired to obtain one or more species whose agency would produce a pleasantly flavored butter, and one or more whose agency, under identical conditions, would produce an unpleasantly flavored butter. For this purpose I have experimented with a large number of species of bacteria. The species used in the experiments were mostly obtained from ripened cream. Visits were made to the Cromwell creamery, the Ellington creamery, and the Wapping creamery in this State. From the vats of ripened cream ready for churning which were found in the creameries at the time of the visit, an inoculation was made into gelatine, roll cultures made therefrom immediately, and these roll cultures were brought home and left in the laboratory for the bacteria to develop. At the end of two or three days the roll cultures showed the presence of numerous bacteria, and the organisms of the different colonies were isolated from the cultures in the ordinary manner. The species of bacteria were then put through a series of plate cultures in order to purify them, and lastly, carried through a series of cultures in various media for the purpose of determining their specific characters. The species thus obtained were numbered, inoculated into agar tubes and kept for further experiment. In addition to the bacteria thus obtained a few species were used which had been isolated from the water of a brook in this vicinity. The reason for this additional source for bacteria cultures is found in the fact that most of the species of bacteria isolated from the cream failed to produce as striking effects upon the butter as was desired for the exhibit of the Columbian Fair, and it was thought that organisms of a different sort might be made valuable for this purpose. The species finally chosen for demonstration at Chicago were, however, all obtained from cream.

Having thus obtained a number of species of bacteria, between thirty and forty in all, the experiments with ripening cream were performed as follows:* Four quarts of milk were obtained daily from a milk dealer and the milk was passed through the centrifugal machine. The cream obtained each day was about one pint. It was divided at once into two lots of half a pint each and each lot placed in a sterilized fruit can. The cream was now put into a pail of water and the water heated by steam until the temperature of the cream reached 69° or 70°C . (158°F .) This temperature was continued for five or ten minutes and then the cream, closed from the air, was set aside to cool, or cooled under the water tap. After cooling it was ready for inoculation and ripening.

In heating the cream up to the temperature of 70°C . (158°F .) as above explained, it was not expected that the cream was sterilized. On the contrary it is well known from many experiments, that such a temperature leaves many bacteria in the cream, especially in the form of spores. Nevertheless, this method, which is generally known as pasteurization, does so reduce the number of bacteria that it was thought to be satisfactory for purposes of our experiment. There would be left in the milk some spores which would germinate somewhat slowly, but only a small number of active bacteria would be present. It was assumed that if to such cream a sufficient quantity of the bacteria of experiment was added in culture, these bacteria being present in such quantities in the cream, would grow rapidly and produce their own effect upon the cream, independent, or nearly independent, of the normal species that chanced to remain after the sterilization. It is, of course, understood that the experiment would be more rigidly correct if the cream could have been sterilized. That, however, was an impossibility, because sterilization, requiring a temperature of at least 100° , also produces in the cream the taste of boiled milk, and that taste is carried over into the butter and produces a flavor in the butter entirely foreign to normal butter. In one or two experiments of this sort that were performed, the taste of the boiled milk was so much more prominent than any other flavor, that the influence of the bacteria of the experiment was entirely obliterated (see experiment 74). The only other method of absolutely sterilizing the cream would have been to

* These experiments were carried out by Mr. William M. Esten, who also had charge of the exhibit at the Columbian Exposition.

heat it to 70° for five or six days in succession, and this process is so long and tedious that it was found to be practically impossible under the conditions of the experiment. Moreover, as the experiments continued, it became evident that the expectation that pasteurization so far destroyed bacteria as to render the experiments successful, was plainly realized. Tests were frequently made by comparing the pasteurized cream without inoculation, with pasteurized cream after inoculation, both lots being ripened for the same length of time at the same temperature. In all such experiments it was found that the uninoculated pasteurized cream was practically unripened at the end of the experiment, while the inoculated cream showed a very marked ripening, due to the bacteria inoculated. This was true only when moderate temperatures were used. At a temperature of 35°C. (95°F.) the pasteurized cream became over-ripened. Moreover, it was found that the experiments in general were uniform in their results. The same species of bacteria inoculated into the pasteurized cream gave, in all cases, under similar conditions, the same results. This, of course, would not have been expected had the few bacteria which chanced to be left in the sterilized cream had any marked effect. As will be seen later some irregularities were probably due to this unavoidable error. The control experiments which were occasionally performed in this way, gave us evidence enough that the method adopted, while not rigidly exact, was sufficiently exact for proper conclusions to be drawn as to the effect of special species. In one experiment, cream was inoculated with No. 27, was then pasteurized and inoculated with No. 18 and ripened. The resulting cream and butter were such as is produced by No. 18 and no trace of No. 27 was seen. Moreover, it must be recognized that if artificial inoculation of cream ever becomes possible in butter making, it will probably never be possible for butter makers absolutely to sterilize their cream. The high temperature required for this, rendering the butter worthless because of its boiled milk taste. Pasteurizing cream at 70°C. (158°F.) may be a practical possibility, though this may be questioned, and for this reason, in addition to those above given, this method of pasteurization was regarded in our experiments as preferable to any attempt at thorough sterilization of the cream. The chance of error, however, made it necessary to repeat experiments many times until uniformity was obtained.

The cultures used for ripening were made as follows: Skimmed milk was placed either in large test tubes or in Erlenmeyer flasks and sterilized by steam on four or five successive days, an absolute sterilization being thus obtained. The amount of the milk in each flask was varied in the different experiments for the purpose of determining the most convenient quantity to use. It was found as the result of many experiments that the best quantity was about one-thirtieth of the amount of cream to be inoculated, bulk for bulk. After sterilization the milk was inoculated with a loop full of a pure culture of the organisms to be tested, obtained from agar tubes. The inoculated milk was then allowed to grow for a varying length of time at varying temperatures, the variations in time and temperature being for the purpose of determining the best conditions under which the growth should occur. There were thus obtained milk cultures of the species to be experimented upon whose age was from one to fourteen days or more. A culture of about two days was found to be most satisfactory.

The cream ripening was conducted as follows: After the pasteurization of the cream as above described, it was cooled to a temperature of 30° C. (86° F.) or lower, and the milk culture was poured into it. The milk can was then closed to prevent the entrance of dust, either by closing the can with its proper cover, or by filling it with a plug of cotton, and the cream was set aside to ripen. In the various experiments the ripening was carried on at three different temperatures, the temperatures chosen being 37°, 27°, and 20° C. (99°, 81° and 68° F.) The experiments also varied as to the length of the ripening, in some cases the ripening being allowed to continue for twenty-four hours at the above mentioned temperatures, and at others for forty-eight hours. During the ripening the cream was occasionally shaken to produce as thorough contact with oxygen as possible and thus to imitate closely the conditions in the vat of the ordinary creamery.

The temperatures used in ripening are all higher than those usually used in creameries. But this was found to be advantageous in our work. The cream could be ripened for forty-eight hours at 20° C. (68° F.) and not be over-ripened, and even the temperature of 27° C. (81° F.) did not injure the cream in twenty-four hours ripening. Such temperatures would have over-ripened cream as ordinarily collected for creameries. The probable explanation is as follows:

1. Our cream was probably not as highly inoculated with bacteria

as normal cream, and a longer time would therefore be required for bacteria growth. 2. Our cream continued a nearly pure culture, and the changes in the cream would be less rapid than when several species were working together. As is well known, a bacteria culture increases most rapidly in the first period of its growth. Later the growth is greatly checked. For this reason, cream would more slowly be changed by a single growing species than by several growing together, even though at first the actual number of individuals was the same. In a few experiments with combined cultures it was found that the ripening was more rapid than with an equal quantity of a pure culture. These facts explain the result which may appear so strange to a butter maker, that cream has been ripened forty-eight hours at 20°C. (68° F.) and then found to be under-ripened and too mild.

After the ripening had continued the proper length of time for the experiment, the cream was tested as to its acid or alkaline reaction. Note was made as to whether bubbles of gas had been produced during the ripening, as to whether the cream had noticeably thickened or not, and very careful note was taken of the odor and the taste of the ripened cream. The cream was then cooled to a temperature of 14½ degrees C. (58°F.) and was then churned. For churning we used an ordinary milk-shaking machine, such as is used by druggists for shaking liquids. The fruit can, about half full of cream, was placed in the shaker and the churning occupied only a very short time, varying from one to ten or twelve minutes, according to conditions, and according to the different species of bacteria that had been used in ripening. After churning, the butter was washed once or twice in water at a temperature of 15°C. (59° F.), and was then worked between butter ladles so as to remove the excess of buttermilk and to imitate as closely as possible the ordinary method of butter working. In some of the experiments salt was added to the butter in the proportion of one to sixteen. In other experiments the butter was worked without salting. It was found that it was preferable not to salt the butter before testing, inasmuch as the salting more or less disguised the flavor produced by the ripening, and in these experiments, in some of which the aroma was quite delicate, it was desirable to have the flavor given to the butter as prominent as possible. It was found that those to whom the butter was submitted for tasting could very much more readily determine the flavor of the butter without the previous

addition of salt, although, in many experiments the flavor was so marked that the addition of salt gave no particular trouble. Salting disguises many a bad-flavored specimen of butter so as to make it passable.

After the butter was thus worked, it was submitted to a number of persons for judgment. In no case did the persons tasting the butter in this way have any knowledge of the particular condition under which the experiments had been made, and did not know, therefore, whether to expect pleasantly or unpleasantly flavored butter. In the verdict given in regard to the butter in the different experiments, there was considerable variation, on the part of different persons, as was to be expected. A butter which one individual would declare excellent, another would regard as only passable, and some persons preferred butter which other persons called strong and rank-flavored. This was anticipated before the experiments began, because, as is well known, the public taste for butter is a very variable one, and it was not to be expected that the delicate shades of difference between differently flavored butters would affect all persons in the same way. Nevertheless, in spite of these differences, there was quite a general consensus of opinion, and all of the marked variations were noticed by all of the persons to whom the specimens were submitted.

These experiments were nearly always carried on in pairs. Sometimes the same species would be used for ripening in each of the pair, but at different temperatures. At other times the same species would be used at the same temperature, but for different periods of ripening. At other times the same species was used at the same temperature, with different periods of ripening, but with a longer period of preliminary growth of the culture in sterilized milk. Sometimes different species were used under identical conditions. Sometimes a can of sterilized cream, uninoculated, would be carried through the ripening process side by side with one inoculated, to compare the ordinary experiments with the effect of no addition of bacteria. In general, the attempt was made, as far as possible, to determine the effect of the different species upon the ripening at different conditions, and to make the experiments as strictly comparable with each other as possible.

The following is the description of the specific characters of the organisms used in the experiments:

No. 2.

Locality.—Found in milk in Middletown, October, 1892, and also in ripened cream in Ellington Creamery, November, 1892.

Morphology.—A micrococcus, size 1 μ . to 1.2 μ . It never forms chains. Grows the same on potato and agar.

Motility.—No motion.

Relation to Air.—Growth under mica, none, or very slight.

Colony on Gelatine.—A slight pit appears, which begins to liquefy. The colony at this time is smooth and uniform. As it grows it breaks up, resulting in a liquid colony with a somewhat clear center, which may contain few granules, and a periferal ring with dense granules. Sometimes the ring is not at the edge and is very dense and distinct.

Gelatine Stab Culture.—Liquefies into a shallow pit with a thick granular yellowish scum. Liquefies slowly, only a quarter of an inch of the gelatine being liquefied after several weeks.

Agar-Agar.—A dry, raised, discreet streak of a salmon or Naples yellow color. Surface is wrinkled, rather tenacious and sticky.

Potato.—A thick, dry mass, which occasionally spreads slightly or sometimes forms a series of distinct beads. Rough and wrinkled. Color varies from white flesh color to a decided brown. Frequently salmon color.

Temperature.—Grows equally well at 20° and 35°. Color not so well developed at 35°.

Milk.—At 20° or at 35° milk is coagulated. Coagulum rather hard with little whey. Orange masses on top. Odor, sour. Alkaline reaction, at least at first. No digestion of the casein occurs. Chemical analysis shows the presence of butyric acid and alcohol.

Bouillon.—Liquid clear, with a slight precipitation and no scum. Later, liquid becomes cloudy and a slight scum forms.

Two varieties of this organism have been found, differing in the brilliancy of the pigment only.

No. 5.

Locality.—Ripened cream from Cromwell creamery, October, 1892.

Morphology.—A large rod 2 μ . by 1 μ ., never forming chains. On agar it is somewhat smaller than on gelatine. No spores observed, occasionally a tendency toward a bi-polar stain noted.

Motility.—

Temperature.—Growth slight at 35°, and green color not produced.

Relation to Air.—Will not grow under mica.

Colony on Gelatine.—A white colony which sinks into a pit with a granular center and a clear rim, spreading into a round, uniformly granular circle with a radiating rim and a greenish tinge.

Gelatine Stab.—Liquefies slowly into a broad funnel, with a thick, tenacious scum. Liquid green and later yellow.

Agar-Agar.—Smooth, moist, rough growth which becomes abundant after a few days and is very sticky. Agar turned green.

Potato.—An abundant white growth with yellowish tinge spreading over the surface of the potato. Smooth and glistening. Sometimes it forms mounds, sometimes a rough, folded mass with pits.

Milk.—Does not curdle at 20°, but turns slowly brownish. At a higher temperature it may form a soft curd with a cloudy whey. Reaction amphoteric or alkaline. Is slowly digested into a lemon yellow, cloudy liquid.

Bouillon.—Uniformly cloudy with abundant sediment. Liquid green.

NOS. 16 AND 16i.

The two varieties named, 16 and 16i, resemble each other very closely in their specific characteristics. It was found impossible to distinguish between them, except by their effect upon butter. In all the experiments 16i produced butter which was decidedly sour, while the butter produced by 16 was less sour and was usually regarded as excellent. The characteristics are as follows:

Locality.—Ripened cream from Mansfield, October, 1892.

Morphology.—An oval rod or micrococcus about 1 μ . in length.

Motility.—Stationary.

Relation to Air.—Grows well under mica.

Temperature.—Grows profusely at 35° as well as at 20°.

Colony on Gelatine.—Forms first a white bead, which spreads rapidly over the surface and is slightly iridescent. Sometimes forms a lobular colony with a raised central nucleus; sometimes there is an outer clear, transparent rim with a raised center. In six days colony reaches dimensions of 2 mm.

Gelatine Stab.—An abundant needle growth with a raised, round, smooth surface growth. Gas frequently produced in gelatine.

Agar-Agar.—A diffused, white, shining growth. Sometimes quite thin, at other times thick with a sharp edge.

Potato.—Very abundant, thick and spreading, white with an irregular surface.

Milk.—Curdles at 35°. Surface with a clear whey, which becomes fragmented and full of bubbles. Does not curdle at 20°. Is strongly acid and shows no digestion.

Bouillon.—Produces a uniformly cloudy liquid with a sediment and a slight scum round the edges of the tube.

No. 18.

Locality.—Mansfield, October, 1892.

Morphology.—A bacillus 2 μ . by 1.4 μ . Occasionally two or three may be seen attached together. Produces spores in its potato growth. Growth on agar the same, though slightly larger.

Motility.—No motion.

Relation to Air.—Grows under mica.

Temperature.—Grows profusely at 35° and at 20°.

Colony on Gelatine.—A white bead which spreads slightly and forms a round, smooth, glistening colony, about 1 mm. in diameter.

Gelatine Stab.—Abundant growth along the needle track. A white nail growth on the surface which spreads in a rather dry layer.

Agar-Agar.—A white, scanty, narrow streak along inoculation line. Sometimes spreads. Not very characteristic.

Potato.—Spreads abundantly into a thick, white, diffused, mottled layer, sometimes raised into mounds. Later it turns decidedly brown and more uniform.

Bouillon.—Produces a uniformly cloudy liquid with a sediment. A slight scum appears after several days.

Milk.—Is curdled slowly at 35°, and becomes acid. At 20° no effect on milk is seen.

No. 19.

Locality.—Cromwell, October, 1892.

Morphology.—A short rod 2 μ . by 1 μ . with rounded ends. It never forms chains, has uniform stain and shows no spores.

Motility.—

Relation to Air.—Will not grow under mica.

Temperature.—Will not grow at 35°.

Colony on Gelatine.—A smooth, round surface colony with slow growth, which becomes after six days a lemon yellow colony about $\frac{1}{2}$ mm. in diameter and sinks into a liquefying pit.

Gelatine Stab.—Slight needle growth. A thin, opaque surface of a lemon yellow color, which becomes sunken in the middle into a pit. After a week the pit is quite deep, but the gelatine does not liquefy.

Agar-Agar.—An abundant, smooth, spreading, lemon yellow growth.

Potato.—An abundant, moist, lemon yellow growth.

Bouillon.—A uniformly slightly cloudy liquid with a very slight sediment.

Milk.—Is rendered slightly alkaline, but is not curdled. After two weeks' growth at 20° the milk becomes partly transparent, showing that its casein has been peptonized. In six weeks milk becomes completely transparent and of a dark brown, almost red color.

No. 20.

Locality.—Cromwell creamery, October, 1892.

Morphology.—A small bacillus 1-3 μ . by .7 μ . A uniform stain. No spores seen. Occasionally adhere in chains of three or four.

Motility.—

Relation to Air.—Will grow under mica.

Temperature.—Grows well at 35° and 20°.

Colony on Gelatine.—A white bead spreading into a round surface colony 1 mm. in diameter, sunken in the middle with a raised rim around the edge.

Gelatine Stab.—Gas produced; slight needle growth and slight, dry surface growth.

Agar-Agar.—Spreads diffusely in a thin, white layer showing branching marks radiating from the central streak.

Potato.—Spreads diffusely into a watery mass with a yellow tinge. Later the growth thickens and the color may become a darker olive.

Milk.—Curdles at 37°, but not at 20°. When curdled it is acid.

Bouillon.—A uniformly cloudy liquid with a sediment. After three weeks a rather tenacious white scum appears.

No. 21.

Locality.—Ellington creamery, November, 1892.

Morphology.—A slender rod 2 μ . by .8 μ . Frequently associated in long chains. No spores seen.

Motility.—Is motile.

Relation to Air.—Will not grow under mica.

Temperature.—Grows well at 35°, though not so well as at 20°. Green color is not formed at 35°.

Colony on Gelatine.—A small, opaque colony which rapidly liquefies into a large, greenish, slightly granular colony. When liquefying, at first the granular mass is associated at the center in a nucleus, but subsequently diffused throughout the liquid.

Gelatine Stab.—Growth is slow. A shallow pit is formed, which becomes a deep, broad funnel. Later there is formed a liquid layer with a scum and a precipitate, and a clear, green liquid between.

Agar-Agar.—Thin, white, almost transparent, moist growth, spreading slightly. Agar becomes greenish.

Potato.—Diffusely spreading, forming a thin, moist, brownish layer.

Milk.—Curdles at 20° and also at 35°. Reaction is alkaline, casein becomes digested slowly.

Bouillon.—A uniformly cloudy liquid with a slight scum. An abundant sediment forms in six days. Liquid very cloudy toward the surface and slightly green. Later a very tenacious scum forms on the surface.

No. 22.

Locality.—Ellington creamery, November, 1892.

Morphology.—A short, oval rod about 1.2 μ .—2 μ . by 1 μ . Variable in size. No spores. Stain uniform.

Motility.—Stationary.

Relation to Air.—Will not grow under mica.

Temperature.—Very slight growth at 35°.

Colony on Gelatine.—A rather thick, spreading colony formed with a central nucleus and a transparent edge, which shows radiant lines.

Gelatine Stab.—Abundant needle growth. A thick, dirty white, opaque surface growth, which later sinks slightly in the gelatine.

Agar-Agar.—A dry, opaque layer with transparent edges. Spreads slightly.

Potato.—A white, narrow, raised streak, which later becomes yellowish.

Milk.—No curdling. Reaction alkaline. Milk becomes slightly translucent.

Bouillon.—Liquid uniformly cloudy, with no scum and only a slight precipitate.

No. 23.

Locality.—Ellington creamery, November, 1892.

Morphology.—A plump rod nearly as long as broad, 1.5 μ . by .8 μ . Sometimes two will be seen, but no chains. Spores numerous. On potato it forms longer rods, 5 μ . in length.

Motility.—Is motile.

Relation to Air.—Grows under mica, producing gas bubbles.

Temperature.—Grows well at 20° and 35°.

Colony on Gelatine.—A small, round, clear, transparent colony, forming a white bead on the surface half a millimeter in diameter. In five days it reaches the diameter of one millimeter and is a small, round, glistening, white colony.

Gelatine Stab.—A thin, rough, almost transparent surface growth.

Agar-Agar.—A white, moderately thick, spreading layer.

Potato.—An abundant white growth, glistening and moist, thick and heaped in mounds. Later distinctly brown.

Milk.—Thickens into a pasty mass, but does not curdle at any temperature. Turns slightly brown after a week or more. Reaction is acid.

Bouillon.—A cloudy liquid with no scum, but an abundant precipitate.

No. 25.

Locality.—Ellington creamery, November, 1892.

Morphology.—A bacillus 2 μ . by .7 μ . Uniform stain, no chains, producing spores.

Motility.—Is motile.

Relation to Air.—Grows well under mica.

Temperature.—Grows well at 35°.

Colony on Gelatine.—Minute, round, clear colony, raised into a bead showing concentric wrinkles. May spread to a diameter of one millimeter with a central nucleus and a darker, broader rim, separated by a partly clear space. The rim may be rough and lobed.

Gelatine Stab.—Abundant needle growth, which is rough and beaded. Slight nail growth on surface spreading widely into a thin, transparent, dry layer, which later becomes quite white.

Agar-Agar.—White, moderately thick growth, not characteristic.

Potato.—A grayish, dry, raised mass, which becomes yellowish and spreads where potato is moist. Color from yellow to a brown ochre.

Milk.—Rendered slightly alkaline, otherwise not changed.

Bouillon.—Uniformly cloudy. A slight sediment which becomes very abundant. After three weeks a scum forms as tenacious white flakes.

No. 26.

Locality.—Ellington, November, 1892.

Morphology.—A slender rod 4 μ . by 1 μ . Size variable. Frequently forms long chains. Bi-polar stain noticed. No spores.

Motility.—Non-motile.

Colony on Gelatine.—A rosette shaped colony with a central dark nucleus and granular rays. Sometimes a double rosette, one round the nucleus and another outside. Rosette lobing may be very coarse or very fine and delicate or sometimes simply granular on the edge.

Gelatine Stab.—A moderate needle growth. A thin, rough, transparent surface dotted with opaque spots.

Agar-Agar.—A very white, moderately thick growth.

Potato.—Gray white, slightly spreading growth with occasionally a faint tinge of yellow.

Milk.—Is not curdled at any temperature. Becomes alkaline. At 20° it becomes slightly transparent in a few days, and after six to eight weeks is converted into a pasty brown, semi-translucent mass with a strong alkaline reaction.

Bouillon.—Uniformly clear liquid. After six days a slight sediment appears. In eight days liquid becomes cloudy and later still a scum forms on the surface which is iridescent and sinks in flakes on being disturbed.

No. 27.

Locality.—Ellington, November, 1892.

Morphology.—A short rod 1.3 μ .—2 μ . by .8 μ . Uniform stain. No spores. No chains.

Motility.—Is motile.

Relation to Air.—Grows under mica.

Temperature.—Grows well at 20° and 35°.

Colony on Gelatine.—Clear, transparent colony under the surface, spreading on the surface into a clear, transparent, mounded colony with wrinkled edges.

Gelatine Stab.—Abundant needle growth, beaded. Slight surface growth at first, later spreading into a thin, transparent surface layer.

Agar-Agar.—White, raised growth, not characteristic.

Potato.—Narrow, raised streak, with a yellowish tinge, spreading where moist.

Milk.—Does not curdle. Is rendered alkaline and acquires a disagreeable odor and a bitter taste. After several weeks digested into a brownish liquid.

Bouillon.—Cloudy with a scum and an abundant precipitate.

NO. 31.

Locality.—Water from a brook, January, 1893.

Morphology.—A bacillus frequently forming long chains. Uniform stain and no spores. Dimensions 1.5 μ . by .9 μ .

Motility.—

Relation to Air.—No growth under mica.

Temperature.—No growth at 35°.

Colony on Gelatine.—Small, round colony with radiating marks under the surface of the gelatine. On the surface a raised bead which becomes surrounded by a clear, granular pit. Granular central mass gradually breaking up and dispersing in the pit.

Gelatine Stab.—Liquefies slowly into a deep funnel, filled with green liquid.

Agar-Agar.—White, smooth, moist, glistening growth, rather diffuse. Agar turned green.

Potato.—Gray and dry, later becomes brownish. Quite thick.

Milk.—Becomes slimy at 20°. Is strongly alkaline. Digestion of casein begins at once and milk rapidly becomes a yellowish green liquid completely digested.

Bouillon.—Cloudy liquid with thick scum. Green one-half inch from top. A sediment collects. After ten days is green throughout and with very thick scum.

With the above described organisms a large number of experiments in cream ripening have been performed, over 150 in all. About two-thirds of them are given in detail in the following table (12). The other experiments either agreed with those described and were for this reason unnecessary, or were omitted since they were isolated and too few to lead to reliable conclusions. The table represents experiments extending from November to April, which were all performed with organisms isolated from cream or water in the months of October or November.

TABLE 12.

Expt. No.	Temperature and Time of Ripening.	Age of Culture.	Appearance of Ripened Cream.	Reaction of Ripened Cream.	Odor of Ripened Cream.	Taste of Ripened Cream.	Butter.
			<i>Organism No. 2.</i>				
1	20° 1 d.	4	-	Neutral,	-	-	{ Good flavor, not enough { flavor for first-class.
2	20° 1 d.	5	-	Neutral,	-	-	{ Good, but mild.
3	25° 1 d.	1	Not thickened,	Alkaline,	Slightly unpleasant,	-	Not churned.
4	25° 1 d.	5	Slightly thickened,	Alkaline,	Slight, unpleasant,	Prominent, but pl's nt,	Excellent, first-class.
5	25° 1 d.	4	Slightly thickened,	Alkaline,	Sweet,	-	Excellent.
6	25° 1 d.	2	Slightly thickened,	Alkaline,	Slightly musty, pl's nt,	Sweet, quite strong,	Finely flavored.
7	28° 1 d.	5	Very slightly thickened,	Alkaline,	Sweet,	Sweet,	{ Excellent flavor, though { not very strong.
8	28° 1 d.	4	-	Neutral,	Sweet,	Sweet,	{ Excellent flavor, but mild.
9	28° 1 d.	-	Slightly thickened,	Alkaline,	Very slight but sweet,	Sweet,	Mild though good flavored.
10	28° 1 d.	7	Slightly thickened,	-	Pleasant,	-	{ Good, but too strong. { Over ripened.
11	28° 1 d.	2	Slightly thickened,	Neutral,	Slightly curdy, faint,	Pleasant, aromatic,	First-class.
12	28° 1 d.	4	-	Neutral,	Slight,	Sweet,	Good, but not first-class.
13	20° 2 d.	1	Little changed,	Alkaline,	Slight,	Sweet, pleasant,	Very good flavor.
14	20° 2 d.	1	Little changed,	Alkaline,	Slight,	Sweet,	Good, but mild.
15	{ 20° 1 d. 37° 2 h. 37° 1 d.	{ - - - }	Little changed,	Neutral,	Slight,	Very little,	Mild, slight burning taste.
16	{ 20° 1 d. 37° 3 h. 37° 1 d.	{ - - - }	Little changed,	Alkaline,	Unpleasant,	Slight,	Good flavor, but too mild.
17	25° 2 d.	4	Little changed,	Neutral,	Slight, musty,	Sweet,	Good flavor, but too mild.
18	25° 1 d.	12	Slightly thickened,	Alkaline,	Sweet,	Sweet,	Excellent flavor, but mild.
19	25° 1 d.	2	Scarcely altered,	Alkaline,	Slight,	Sweet,	Good, mild.

20	25°	1 d.	4	Scarcely altered,	-	-	-	-	Sweet, pronounced,	-	Mild, stronger than Expt. 19.
22	28°	1 d.	22	Full of bubbles,	-	-	-	-	Musty, sweet, pleasant,	-	{ Very mild, good flavor, but peculiar.
23	28°	1 d.	21	-	-	-	-	-	Sweet,	-	Not good.
24	28°	1 d.	8	Not altered,	-	-	-	-	Sweet,	-	{ Sticky, full of slime, good flavor.
25	35°	1 d.	2	C'd'd, hard, full of bubbles,	-	-	-	-	-	-	Worthless.
26	35°	1 d.	14	Over-ripened, worthless,	-	-	-	-	-	-	Very bad.
27	28°	1 d.	4	Slightly thickened,	-	-	-	-	-	-	Good, but mild.
28	{ 30° 9 h. 20° 15 h.		{ 11	Unaltered, slight gas,	-	-	-	-	Slight, pleasant,	-	Musty, but pleasant.
29	23° 48 h.		5	Slightly changed,	-	-	-	-	Slight,	-	Good, mild.
30	25° 48 h.		2	Slightly changed,	-	-	-	-	Excellent,	-	Prominent flavor, excellent.
31	25° 48 h.		1	Slightly changed,	-	-	-	-	Good,	-	Rather mild.
<i>Organism No. 27.</i>											
32	25°	1 d.	6	Slightly thickened,	-	-	-	-	Unpleasant,	-	Bitter and bad.
33	25°	1 d.	3	Slightly thickened,	-	-	-	-	Bitter,	-	Bitter and bad.
34	28°	1 d.	7	Slightly thickened,	-	-	-	-	Bitter,	-	Strong and unpleasant.
35	28°	1 d.	4	Slightly thickened,	-	-	-	-	Bitter,	-	Bitter and bad.
36	25°	1 d.	-	Slightly thickened,	-	-	-	-	Slight, unpleasant,	-	Slightly bitter.
37	28°	1 d.	7	Slightly thickened,	-	-	-	-	Bitter,	-	Bitter and bad.
38	20°	2 d.	21	Slightly thickened,	-	-	-	-	Bitter,	-	Bitter and bad.
39	20°	2 d.	7	Slightly thickened,	-	-	-	-	Bitter,	-	{ Bitter and bad, burning taste on tongue.
40	20°	2 d.	4	Slightly thickened,	-	-	-	-	Bitter,	-	Bitter and bad.
41	35°	2 d.	14	{ Over-ripened, worth- less, not churned.	-	-	-	-	-	-	-
42	25°	2 d.	21	Thickened,	-	-	-	-	Bitter,	-	Bitter, burning, worthless.
43	20°	2 d.	5	Thickened,	-	-	-	-	Bitter,	-	Bitter, burning, worthless.
44	20°	2 d.	-	{ So badly ripened that it was not churned.	-	-	-	-	-	-	-
45	25°	2 d.	10	Slightly thickened,	-	-	-	-	Bitter, strong,	-	Bitter, burning, worthless.
46	20°	2 d.	1	Slightly thickened,	-	-	-	-	Bitter, strong,	-	Bitter, burning, worthless.

TABLE 12.--(Continued.)

Expt. No.	Temperature and Time of Ripening.	Age of Culture.	Appearance of Ripened Cream.	Reaction of Ripened Cream.	Odor of Ripened Cream.	Taste of Ripened Cream.	Butter.
47	24° 1 d.	—	<i>Organism No. 5.</i> Slightly thickened,	Acid,	-	-	{ Rather gummy, not specially good.
48	27° 1 d.	—	Rather thick, foamy,	Acid,	Slight,	Soured,	{ Strong, rather disagreeable flavor, slightly burning sensation.
49	20° 1 d.	—	Somewhat foamy,	-	Peculiar,	Unpleasant,	{ Good flavor.
50	{ 20° 21 h. 37° 3 h.	{ — —	Not thickened,	-	Slight,	-	{ Very slight taste.
52	27° 1 d.	Ag'r	<i>Organism No. 16.</i> Cream, very thick, frothy,	Acid,	Unpleasant,	-	{ Churns with difficulty, mild, unpleasant flavor, not good.
53	{ 37° 7 h. 33° 17 h.	{ 3 4	Thin, - Frothy, with gas bubbles,	Acid, Acid,	Unpleasant, Sour, prominent,	Sour, not bitter, Slightly sour,	{ Strong, over-ripened.
54	20° 2 d.	Ag'r	Not thick,	Acid,	Pleasantly sour,	Sour,	{ Good, not very much taste.
55	20° 2 d.	{ 18 4	Slightly thick, Slightly thickened,	Acid, Acid,	Sour, unpleasant, -	Sour, pleasant, Slightly sour,	{ Too strong, seemingly over-ripened.
56	{ 20° 22 h. 37° 3 h.	{ 18 4	Slightly thick, Slightly thickened,	Acid, Acid,	Sour, unpleasant, -	Sour, pleasant, Slightly sour,	{ Slight taste, not very good.
57	23° 1 d.	—	<i>Organism No. 16i.</i> Thin, unaltered,	Acid,	Unpleasant,	Bitter, strong,	{ Good, slightly sour taste.
58	{ 37° 7 h. 35° 17 h.	2	Thin, unaltered,	Acid,	Unpleasant,	Bitter, strong,	{ Intensely bitter.
59	20° 1 d.	2	Unaltered,	Acid,	Neutral,	Bitter, sour,	{ Sour, bitter and burning.

60	20° 2 d.	Ag'r	Unaltered, -	-	Acid,	-	Peculiar,	-	Sour, bitter,	-	{ Strong and bitter with burning taste.
61	28° 1 d.	3	Moderately thick, -	-	Very acid,	-	Like ripened cream,	-	Sharp, sour,	-	{ Quite good, slight burning taste.
62	20° 1 d.	1	Thickened, -	-	Acid,	-	Fresh, creamy smell,	-	Good,	-	{ Good taste, but too strong.
63	37° 1 d.	1	Thin, thick layer on top,	-	Very acid,	-	Strong, sickish,	-	Disagreeable, sharp,	-	{ Strong, bitter, burning, very bad.
64	28° 1 d.	2	Unaltered, -	-	Acid,	-	Disagreeable, sour,	-	Sour,	-	{ Strong and disagreeable.
65	28° 1 d.	4	Unaltered, -	-	Acid,	-	Strong, sour,	-	Very sour,	-	{ Bitter and burning.
66	23° 2 d.	1	Unaltered, -	-	Acid,	-	Strong, sour,	-	Very sour,	-	{ Bitter and burning.
<i>Organism No. 18.</i>											
67	28° 1 d.	13	-	-	Acid,	-	Sour, penetrating,	-	Slightly bitter,	-	{ White, fair, but peculiar taste.
68	37° 1 d.	12	Thick, full of gas, -	-	Strong acid,	-	Oily, musty,	-	Clear, sour,	-	{ Strong, oily, cheesy, worthless.
69	37° 1 d.	-	Thick, -	-	Acid,	-	Sour, disagreeable,	-	Sour, sickish,	-	{ Strong, rank, bad taste.
70	{ 20° 22 h. 37° 3 h.	{ 6 6	-	-	Neutral,	-	Slight, unpleasant,	-	Unpleasant,	-	{ Moderately good, slightly burning.
71	{ 20° 22 h. 37° 3 h.	{ 2 2	-	-	Acid,	-	Bitter,	-	Bitter,	-	{ Slightly strong, rank taste.
72	25° 1 d.	2	Not thickened,	-	Acid,	-	Sickish, strong,	-	Sour,	-	{ Strong, rank taste, over-ripened.
73	28° 1 d.	-	Not thickened,	-	Acid,	-	Sickish, strong,	-	Sour,	-	{ Slightly strong, rank taste.
<i>Organism No. 19.</i>											
74	20° 1 d.	-	No change, -	-	Neutral,	-	Scalded taste,	-	-	-	{ Tastes of scalded milk.
75	37° 1 d.	-	{ Thickened, oily, full of gas bubbles, strong. }	-	Acid,	-	Musty,	-	Sour,	-	{ Peculiar, cheesy, bad.
76	20° 1 d.	10	Unchanged,	-	Alkaline,	-	Unpleasant, cheesy,	-	-	-	{ Tasteless.
77	20° 2 d.	4	Unchanged,	-	Alkaline,	-	Slight,	-	Smarty, sweet,	-	{ Moderately good, but rather strong.

TABLE 12.—(Continued.)

Expt No.	Temperature and Time of Ripening.	Age of Culture.	Appearance of Ripened Cream.	Reaction of Ripened Cream.	Odor of Ripened Cream.	Taste of Ripened Cream.	Butter.
			<i>Organism No. 20.</i>				
78	23° 1 d.	3	Slightly thick, -	Acid, -	- - - -	- - - -	{ Good flavor, texture sharp, slightly pungent.
79	{ 20° 22 h. 37° 2 h.	-	Unchanged, -	Neutral, -	- - - -	Sweet cream, -	{ Good, but not enough taste.
80	28° 1 d.	-	Not thickened, gas, -	Acid, -	Sour, slightly musty, -	Slightly sour, -	{ Rather strong and unpleasant taste, not good.
81	28° 1 d.	7	Not thickened, -	Acid, -	Musty, - - - -	Musty, sour, -	{ Slight musty taste, unpalatable.
82	20° 2 d.	21	Gas accumulates, thin, -	Acid, -	{ Pleasant, like ripened cream, -	Slightly sour, -	{ Quite good.
83	20° 2 d.	9	Quite thick, no gas, -	Acid, -	Peculiar, - - - -	Slightly sour, -	{ Good, rather too strong.
			<i>Organism No. 26.</i>				
84	27° 1 d.	-	Thin, - - - -	Alkaline, -	Fresh, rich, - -	Good, - - - -	{ Excellent, rather mild.
85	20° 2 d.	7	Unaltered, - - - -	Alkaline, -	Sweet, pleasant, -	Sweet, pleasant, -	{ Very mild.
86	20° 2 d.	7	Moderately thick, -	Neutral, -	Slight, - - - -	Pleasant, creamy, -	{ Good, mild.
87	23° 1 d.	15	Unchanged, - - - -	Alkaline, -	Slight, - - - -	Sweet, - - - -	{ Good.
88	23° ? 1 d.	5	Unchanged, - - - -	Alkaline, -	Pleasant, slight, -	- - - -	{ Good, mild.
89	23° ? 1 d.	-	Unchanged, - - - -	Neutral, -	Pleasant, slight, -	- - - -	{ Good, mild.
			<i>Organism No. 31.</i>				
90	23° 1 d.	-	Thickened, - - - -	Neutral, -	Decaying, - - - -	Bad, - - - -	{ Fluffy, with bad taste and worthless.
91	23° 1 d.	3	Not thick, - - - -	Alkaline, -	Peculiar, - - - -	Slight, - - - -	{ Very mild, somewhat smarting.
92	28° 1 d.	-	Thickened, - - - -	Alkaline, -	Bad, - - - -	Bad, - - - -	{ Sickish and worthless.

SUMMARY OF THE RESULTS SHOWN BY THE TABLE.

From the experiments thus tabulated (see table 12 before) can be drawn certain general results as to the effect of the different species. These conclusions, with some further details, may be summarized as follows:

Species No. 2.

From the table it will be seen that No. 2 makes good butter though of a rather mild flavor, and that it makes little difference whether the ripening be carried on two days at 20° or one day at a higher temperature, but the best results were obtained after forty-eight hours ripening at 20°. Except with a very high temperature No. 2 will always produce good butter. The flavor, while excellent, is not quite like that of first class creamery butter. We see further that it makes little difference in the results whether the culture of inoculation be a fresh culture (one or two days) or an older one. Practically it was found more convenient to use fresh cultures. Everyone to whom the butter was submitted regarded it as excellent but mild, and it was frequently preferred to creamery butter with which it was compared. Slight differences in the results of these tables are probably due to errors introduced by other species accidentally present in the milk. It was noticed in most experiments that the ripening, if prolonged, injured the texture of the fat so that the grain of the butter was not good.

Species No. 22.

It will be seen from the table that No. 22 makes good butter but also rather mild. When compared with No. 2 in parallel experiments, preference was usually given to No. 2, although there was little difference between the two. It will be seen also that No. 22 ripens cream slowly, and forty-eight hours at 20° was never too long to produce the best results. It would stand twenty-four hours at 28° without difficulty, but 35° rapidly destroyed the cream and ruined the butter. In experiment No. 22 the milk and cream were slimy, a fact which explains the bad butter. Nos. 2 and 22 produced better butter than any other species of bacteria experimented with. Frequently the butter was pronounced decidedly superior to creamery butter with which it was compared.

Species No. 27.

No. 27 uniformly ruins the butter whenever it has an opportunity to grow in the cream. It grows readily at all temperatures and always produces bad smelling cream and bitter butter. The effect was the same whether allowed to act one or two days, although more noticeable, of course, in the longer periods. By reference to the tables it is seen that Nos. 2 and 22 produce an excellent, mild-flavored butter under identically the same conditions as those under which No. 27 produces a very bad butter. Experiments No. 33 and one of the same date, not in the tables, were especially instructive. The two lots of cream for the day were both inoculated with No. 27 and then pasteurized at 70°. One was then inoculated with No. 27 and the other with No. 2. Both were then ripened twenty-four hours. One gave the bitter butter of No. 27, the other the good butter of No. 2; showing that pasteurizing would destroy the organism No. 27, should it chance to be in the cream.

Species Nos. 2, 22 and 27.

These three organisms were those upon which the largest number of experiments was performed, inasmuch as they proved to be the most promising for the purpose for which the experiments were originally designed. The other organisms were not used so many times for the purpose in our experiments, and the results are therefore not quite so definite. These three were finally chosen for the exhibit at Chicago. Nos. 2 and 22 to show species producing good butter, and No. 27 a species producing bad butter. Later No. 16i was added to the list.

Species No. 5.

Experiments 47-50 were among the earlier experiments and the cream was inoculated directly from an agar culture. In experiment 49 the cream, in order to compare with experiment 50, was not pasteurized. Plate cultures were made from the ripened cream of both, and while No. 49 showed a variety of species, ripened cream of No. 50 was nearly a pure culture. These experiments were insufficient to determine satisfactorily the effect of No. 5 on butter.

Species Nos. 16 and 16i.

From experiments 52-65 it will be seen that Nos. 16 and 16i differ plainly in their effect on butter. No. 16i always produces

bitter, sour butter, while No. 16 made very good butter in all cases. So marked was the bitter taste of 16i that it was used in many experiments at the Columbian Fair to show the injurious effect of certain species of bacteria on the butter aroma. The difference between these two organisms is very remarkable considering that their specific characters are almost identical. After having worked out the characters as shown on page 51, I concluded that the species were identical, but repeated experiments in ripening cream showed an absolutely uniform difference in the resulting butter, and the conclusion was inevitable that at least there was a physiological difference between them. This result, while surprising, is not unique, for other species or varieties have been found to be separated by equally slight differences. Nencke (*Cent'v't. f. Bact. u., Par. IX, p. 304*) has found a bacillus differing from *B. coli commune* only in producing a different chemical form of lactic acid. Other instances might be cited.

Species No. 18.

From experiments 68-73 it will be seen that No. 18 produces very poor butter. It is not so bad as that of Nos. 27 or 16i but is of a decidedly poor quality.

Species No. 19.

In experiment No. 74 the cream was heated to 100° instead of 70° which explains the scalded milk taste. No. 19 will not grow at 35° (see page 52). The ripening of the cream in experiment 75 was not, therefore, due to No. 19 but to the organisms which resisted 70° used in pasteurization and were forced into rapid growth by the high temperature of ripening. From experiments 74-77 it will be seen that No. 19 is not favorable to butter ripening, butter acquiring a rather strong taste under its influence. The butter was not very bad, however, and would readily pass in market as a second quality butter.

Species No. 20.

The butter in experiments Nos. 78-82 differed somewhat in quality, sometimes being quite good and at others not so good. The differences were very slight, however, and would lead to the conclusion that No. 20 produced very slight effect on butter flavor. So slight was it that the organism was soon abandoned as unpromising.

Species No. 26.

In experiment 89 the cream was inoculated with the buttermilk from experiment No. 87. This species produces excellent butter.

Species No. 31.

No. 31 was obtained from water of a brook. Its effect on butter was universally bad.

In addition to the organisms above referred to in tables, cream has been ripened with quite a number of other species not described. A few well known species of bacteria were also used as follows :

A culture of *Bacillus acidi-lactici* received from Germany was found to make unpleasant-tasting butter, as has been previously shown by Storch.

The species *Micrococcus freudenreichi*, received through the kindness of M. Freudenreich, was used according to the method above described, and was found to produce a good-tasting though very mild butter, which was, however, rather soft and fluffy in consistency.

Bacillus katz produced butter with a tolerably good taste, and would be regarded as moderately good butter.

Bacillus schafferi was found in several experiments to produce butter with an unpleasant taste, which was always regarded as a poor quality of butter.

Several points of general interest have been shown by the experiments above given, which may be summarized here. In the first, place, it has been proved in all cases that a temperature as high as 35° C., even for a few hours, is almost sure to over-ripen the cream and produce bad butter. Moreover, it was found that pasteurized cream, even though not subsequently inoculated, would become ripened in twenty-four hours at this temperature, indicating, of course, that the spores left in the cream developed rapidly enough at that temperature to produce marked results. Evidently a temperature of 35° cannot be used for ripening in such experiments. Temperatures of 28° and 23°, however, could be used for twenty-four hours without difficulty, the uniformity of the experiments at this temperature showing that the cream was ripened chiefly by the artificial culture inoculated. At the temperature of 20° the ripening could be continued for two days without trouble, and in no case was an over ripening produced in this time with any of the pure cultures used.

The experiments, as stated in the introduction, have always been performed in pairs, and the separate consideration of the results of some of these pairs will be instructive as indicating the success of the experiments, and the striking results of different species under similar conditions. A few such pairs only will be selected for description.

On February 4th two lots of cream were pasteurized as usual, one inoculated with No. 2, the second with No. 27. Both of them were allowed to stand at 23° for two days. At the end of that time, No. 2 cream had a slight musty smell, with a neutral reaction, and produced a very good butter, which was quite mild. No. 27 at the same time produced a vile-smelling alkaline cream, which resulted in a bitter, vile-tasting butter which was very poor.

On January 26th two lots of cream were pasteurized, one inoculated with No. 22, the other with No. 2. They were ripened one day at a temperature of 23° . Each of them produced a sweet-smelling, sweet-tasting, alkaline cream. Each produced an excellent grade of butter, and it was difficult to choose between them.

On January 21st the two lots of cream were heated as usual, one inoculated with No. 26, the second with No. 27. Both were left at a temperature of 20° for two days. Both became alkaline with a pleasant, mild odor. No. 26 had a pleasant, sweet taste, and gave butter with scarcely any aroma. No. 27 gave a sour-tasting cream, resulting in a bitter butter with a smarting taste.

January 23d both lots of cream were sterilized as usual, one inoculated with No. 16i, the second with No. 2. Both were placed at 27° for one day. No. 16i gave an acid, disagreeable-tasting and smelling cream, and a strong, disagreeable aroma to the butter. No. 2 produced a slightly acid cream with a pleasant odor and taste, and an excellent quality of butter.

On January 20th two lots of cream were heated as usual, one inoculated with No. 18, the second with No. 2. Both were left at 28° for one day. No. 18 produced a sickish-smelling cream, slightly sour and bitter, with a strong, rank taste. No. 2 produced slightly alkaline, sweet-tasting cream, with a pleasant, mild-tasting butter.

January 16th two lots of cream were heated as usual, one inoculated with No. 23, the second with No. 18. Both were left at 20° for twenty-two hours. The cream of both became slightly acid. Both were then placed at 37° for three hours. No. 23

became slightly more acid but produced very good butter. No. 18 became decidedly acid and bitter and produced strong, rank butter.

The consideration of the pairs of experiments as shown above, plainly shows the difference in the butter of different species of bacteria when used in ripening the cream, and, in addition, indicates that the method of experiment was rigid enough to obtain at least approximate results in all cases.

Another point brought out clearly in these experiments was the effect of the washing of butter. Nearly all of the flavor produced by the ripening of the cream was in the buttermilk, and the taste of the butter was very much more prominent without thorough washing than it was after such washing. If the butter was washed long enough, all of the aroma would be washed out, while without any washing at all, the taste was most prominent. The butter aroma is then not due to changes in the fat, but to some other constituents of the cream. For this reason it was our custom to taste the butter before any washing had occurred, as well as after the working, and in this way a stronger effect was noted and the differences between the organisms made out with more ease. This fact, that the aroma is due to the buttermilk, is not a new one, but it was plainly brought out by the experiments.

It should be stated that in all of these experiments the differences in flavor of the resulting butter were less than had been anticipated before the experiments began. The effect upon the taste and flavor of the ripened cream of the different species of bacteria was very marked indeed, and the effect upon the taste of the butter before washing was equally striking. After the washing and the working, which removed a considerable portion of the buttermilk, the differences in flavor were very much less noticeable, so much so that in some of the experiments it required the utmost attention to make out the appropriate differences between different specimens of butter. It is true that the differences above noted in the experiments were always seen in the specimens of butter tested, but it is equally true that those differences were not in many cases very striking ones. Many of the forms of butter which have been described as poor or moderate would probably pass muster as tolerably good butter. At the same time, in the case of a few of the organisms, especially No. 27 and No. 16*i*, the effect upon the butter was in itself very

striking, and no one failed to perceive the marked disagreeable flavor. The total result of these experiments, however, has been to indicate that the effect upon the flavor of butter, while noticeable, is not so striking as was at the outset expected. At the same time the effect was sufficient to make the differences between the fine, delicately flavored butter and the unpleasant, strong-tasting butter which results from an improper ripening; in other words, the differences between the very highest quality of butter and that of an inferior grade.

Another point of much significance was noted. Of the large variety of species of bacteria found in ripening cream the number which produce poor butter is very small. Among the 20 species already experimented with, only three produced strikingly bad effects, while all the rest gave good butter or had no marked influence. This is a matter of considerable importance as bearing upon dairy interests. It indicates that no particular species of bacteria is needed to produce a good aroma, but that nearly all of the species liable to get into the cream under normal conditions, will give moderately good results. Some, indeed, are better than others for the purpose, and some really produce injurious effects, but the majority of species are either directly advantageous or neutral in their action. It must be remembered, however, that the source of these organisms was cream from first-class creameries, where the beneficial species must be supposed to outnumber the injurious ones. What result would have been obtained if a lot of cream from an inferior dairy had been used as a starting point, cannot be stated, but the result remains that good conditions may be depended upon to produce favorable varieties of bacteria in abundance.

Somewhat akin to the above is the general observation that no single species produced a typical ripening of cream, or the usually expected flavor in the butter. Although many of them produced excellent butter, yet in every case the verdict would be given that the flavor was not exactly that of normally ripened butter. This is not to be wondered at, for it is hardly to be expected that any one species would produce the same result as that produced by many species growing together. Experiments with combinations of species have therefore been undertaken, but the results are not yet complete.

It will be noticed that most of the species experimented with, produced an alkaline reaction, the reason being that a large part

of the species isolated from ripening cream, showed this peculiarity. The few acid-producing species isolated did not produce so good effects on the butter as the alkaline producing species. Further experiments with acid-producing species are needed, however.

SUMMARY.

The most important points taught by these experiments may be summarized as follows:

1. Different species of bacteria grown in the cream while ripening have different effects upon the butter flavor. The differences in the resulting butter aroma are not very prominent in most cases, but are decided enough to make the difference between a first-class grade of butter and a second class.

2. Pasteurizing cream at 70° C. will so largely destroy the bacteria in it, that a pure culture of bacteria subsequently inoculated will produce its proper effects, not materially affected by the few organisms left in the cream after pasteurization.

3. Most species of bacteria found in cream of a good creamery produce good butter. The number which injure the flavor of the butter is small.

4. No one species of those experimented with, when used alone for ripening cream, produces a typically flavored butter, though many of them produce butter which is excellent in flavor and which was preferred to that of the normal ripening.

A STUDY OF RATIONS FED TO MILCH COWS ON
SIXTEEN DAIRY FARMS IN CONNECTICUT.

BY CHAS. D. WOODS AND C. S. PHELPS.



In the Report of this Station for 1890 (pages 180 and 181), in an article by Professor Atwater on the fuel value of feeding stuffs, reference was made to six rations fed by leading New York dairymen and compiled by the New York State Station.* These were cited as illustrations of the wide range in the quantities of protein and of total estimated energy (fuel value) in the rations on different farms, and the importance of a more thorough study of actual feeding practice of dairymen. The hope was then expressed that "circumstances may be such as to permit an inquiry regarding kinds and amounts of feeding stuffs used by Connecticut dairymen."

During the winter of 1892-3, it was found practicable to begin such an investigation. For this purpose, Mr. Harry G. Manchester, a graduate of the Storrs School of the class of 1891, was employed as a special representative of the Station, to visit different dairy farms in the State, and make systematic observations of the cows, their feeding, care, milk-production and kindred subjects.

Each herd was selected by one of us (C. S. P.), after a personal inspection or after sufficient correspondence to satisfy ourselves of its fitness for the proposed test, and was frequently visited while the test was being made.

Mr. Manchester usually went to a farm on a Monday morning, arriving in time to begin the test at noon of that day, and remaining until the following Saturday. The interval between Saturday noon and the following Monday was long enough to go to another place with the needed apparatus and make preparations for a test to begin at noon on Monday. This made a period of five days at each place, and with two exceptions this was the

* New York State Station Bulletin No. 17, (new series).

length of time given to the study of each of the sixteen herds visited. In this first winter's work, which was regarded as preliminary to an investigation that might extend over a series of years, it was thought better to examine a relatively large number of herds, each during a short period, than to make the periods longer and the number of herds less.

The chief points upon which information was obtained were:—

Number of animals in the herd.—In considering the number of animals, only those which came into the test were included. Usually these were all of the cows on the farm which were in milk at the time of the test.

Breed, age and approximate weight of each cow.—The breed and age were obtained as accurately as possible from the owner. Since it was not practicable to take to the farm scales large enough on which to weigh the cows, the weights were estimated. This estimation was made in each case by the Station representative, and it is hoped that the errors of judgment may run more or less equally through all the herds examined.

Number of months since last calf.—In most cases the time at which the cow dropped her last calf was known.

Number of months till due to calve.—There was, of course, more or less uncertainty in this regard.

Weights of milk-flow for the five days.—The milk of each cow at each milking was weighed as soon as milked, to the nearest tenth of a pound, by the Station representative.

Percentages and amounts of butter-fat in the milk.—A sample of the milk of each cow, at each milking, was taken for the determination of the quantity of butter-fat. The Babcock method of fat determination was employed. From the percentages of butter-fat in the milk, and the total weights of the milk, the daily yields of butter-fat were obtained.

Kinds and weights of foods used.—The feeder was requested to use the same kinds and amounts of feeding stuffs during the test period as he had previously used. The quantity for each animal was weighed by the Station representative just before feeding. Any portions of the food left uneaten by the cows were carefully weighed, and due allowance was made for these uneaten residues in estimating the amounts daily eaten. During the test, usually on the third day, samples of each food used were carefully taken and at once sent to the laboratory for analysis. From the results

of the analyses and the weights fed, the total nutrients (protein, fats, nitrogen-free extract and fiber) fed each day were calculated. By the use of digestion coefficients, more or less accurate estimates were made of the weights of digestible nutrients in each day's ration.

The names and post-office addresses of the owners of the herds studied by the Station are given in the following list, together with the dates at which the Station representative was at the farm. At the left, in the first column of figures, there is given a reference number for each herd. In the remaining tables and in the discussion, the herds and the rations fed are referred to by these reference numbers.

Names and Post-office Addresses of Owners of Herds Studied, Dates at which they were visited and Reference Numbers of Herds.

NO. OF HERD.	NAME AND P. O. ADDRESS OF OWNER.	DATE OF TEST.
		1892.
1, - -	W. S. Crane, Willimantic.	Nov. 30-Dec. 2.
2, - -	N. D. Potter, South Coventry.	Dec. 5-9.
3, - -	Samuel Stockwell, West Simsbury.	Dec. 12-17.
4, - -	C. P. Case, Simsbury.	Dec. 19-24.
5, - -	Edward Manchester, West Winsted.	Dec. 26-31.
		1893.
6, - -	Isaac Barnes, Collinsville.	Jan. 2-7.
7, - -	Elbert Manchester, Bristol.	Jan. 9-14.
8, - -	Edward Norton, Farmington.	Jan. 16-21.
9, - -	H. W. Sadd, Wapping.	Jan. 23-28.
10, - -	John Thompson, Broad Brook.	Jan. 30-Feb. 4.
11, - -	E. F. Thompson, Warehouse Point.	Feb. 6-11.
12, - -	R. E. Holmes, West Winsted.	Feb. 13-18.
13, - -	James B. Blivin, Baltic.	Feb. 27-Mch. 4.
14, - -	George W. Woodbridge, Manchester Green.	Mch. 6-11.
15, - -	Harvey S. Ellis, Vernon Centre.	Mch. 13-18.
16, - -	Chas. P. Grosvenor, Abington.	Mch. 20-25.

Table 13, which follows, gives a summary of the statistics of the herds visited. In this table and in the others which follow, the following abbreviations are used:

ABBREVIATIONS USED IN REPORT OF COW DIETARIES.

Ay.=Ayrshire.	Gy.=Guernsey.	P.=Pure Breed.
Dev.=Devon.	Hol.=Holstein.	R.=Registered.
Dur.=Durham.	Jy.=Jersey.	Sw.=Swiss.
G.=Grade.	Nat.=Native.	

TABLE 13.
Condensed Statistics of Sixteen Dairy Herds Studied by the Station.

NUMBER OF HERD.			Length of Test.	NUMBER OF ANIMALS IN TEST.														Average Weight.	Average Age.	Mos. Since last Calf.		
				Ayrshire.		Devon.		Durham.		Guernsey.		Holstein.		Jersey.		Swiss.					Native.	Total.
				R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.					
1,	-	-	3	1	-	1	-	-	-	8	1	-	-	-	3	-	-	-	14	900	5	10
2,	-	-	4	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1	13	900	7	5
3,	-	-	5	-	-	-	-	-	-	1	-	-	-	3	8	-	-	1	13	600	5	6
4,	-	-	4	-	-	-	-	-	-	-	-	-	1	18	-	-	-	-	19	800	5	4
5,	-	-	5	-	1	-	-	-	-	-	1	2	-	5	-	-	6	-	15	800	6	4
6,	-	-	5	-	-	-	-	-	-	1	-	-	1	-	3	2	-	-	10	900	6	7
7,	-	-	5	-	2	-	-	-	1	-	-	5	-	6	-	-	3	17	825	6	6	
8,	-	-	5	-	-	-	-	-	-	5	6	-	-	-	-	-	1	12	750	5	3	
9,	-	-	5	-	-	-	-	-	-	5	6	-	-	-	-	-	1	12	900	7	5	
10,	-	-	5	-	-	-	-	1	-	-	-	-	4	13	-	-	-	18	850	5	3	
11,	-	-	5	-	-	-	-	-	-	-	-	-	-	18	-	-	-	18	825	5	5	
12,	-	-	5	-	-	-	-	-	-	3	-	1	9	-	-	-	7	20	875	6	7	
13,	-	-	5	-	1	-	1	-	2	-	1	6	6	-	-	-	1	19	800	5	10	
14,	-	-	5	-	-	-	-	-	-	-	-	-	10	-	-	-	-	10	875	7	4	
15,	-	-	5	-	1	-	-	-	-	-	-	-	18	-	-	-	-	19	850	6	5	
16,	-	-	5	-	-	-	7	-	-	3	-	1	-	-	-	-	5	20	900	6	7	
				1	5	1	8	1	3	19	19	3	9	16	138	3	2	26	254	850		

As shown in table 13, the sixteen herds examined contained 254 milk-giving cows, or an average of about sixteen per herd. The smallest herd contained ten cows; the largest twenty. Seven breeds and grades were represented besides some animals of unknown pedigree. Forty-four cows, or 17 per cent. of the whole were of pure breed; 184, or 73 per cent. of the whole, were grades, and 26, or 10 per cent. of the whole, were "natives," that is, animals without any special breeding so far as known. One hundred and fifty-four, or 60 per cent. of the whole, were either pure or grade Jerseys, and 38, or 15 per cent. of the whole, were pure or grade Guernseys. While no effort was made to select herds of any particular breeding, it happened that three-fourths of all the animals of these herds were, to a greater or less extent, from stock originally from the Channel Islands.

The average ages of the animals of each of the sixteen different herds ranged from five to seven years, six being about the average age of the animals of all the herds taken together. The youngest animal was two years old (in third year) and the oldest was 17 years. Fifty-eight of the cows were under four years, 193

were between four and twelve, and three were over twelve years old. One hundred and sixty of the 196 animals which were four years old or older, were in the period of lactation (from flush to eight months past calving) during which the largest yields of milk and butter-fat are expected.

Tables 14 to 29 inclusive contain the results, in considerable detail, of the studies of the sixteen different herds. They are all alike in arrangement, and a description of one will serve for all. Each table contains the condensed results for a herd. Table 14, for instance, gives statistics for herd No. 1.

The first (upper) part of the table gives a reference number of each animal, its breed, age, weight and number of months since last calf. The smallest daily milk flow, the greatest daily milk flow and the total yield of milk for the five days are given in the next three columns. In the three following columns are given the lowest, highest and average percentages of fat found in the daily milk of each cow for the period of five days. The figures were obtained by adding together the five daily determinations and taking the average, hence this actual average is not always half way between the highest and lowest. The yield of fat is given in the last three columns of the first or upper part of the table. The minimum and maximum yields of fats were obtained by multiplying each day's milk by its percentage of fat; the lowest number thus obtained gives the minimum daily yield of fat, and the largest the maximum yield of fat. It is to be noted that these numbers are not the same as would have been obtained by multiplying the minimum and maximum daily milk flow by the minimum and maximum percentages of fat. The total yield of fat for the five days was found by taking the sum of the daily yields of butter-fat.

The second, or lower part of each table, gives the kinds and amounts of the different food materials eaten *per day per 1,000 pounds live weight*, and the weights of the total and digestible nutrients (protein, fats and carbohydrates) which they furnished. As stated previously, all of the different feeding stuffs used in these rations were analyzed, and from the results of these analyses the weights of the total nutrients furnished by the different coarse fodders and concentrated foods were obtained. The results of these analyses are given on pages 17-27 of this Report. The method employed in calculating the fuel value or potential

energy furnished by the different foods, is explained on page 17 of this Report.

The weights of digestible nutrients in the rations were obtained from the weights of total nutrients by the use of factors (coefficients of digestibility) obtained from the results of digestion experiments in this country and Germany. So far as possible, the factors obtained in American digestion experiments were employed. The following tabulation gives the digestion coefficients here employed.

Coefficients of Digestibility used in calculating the Digestible Nutrients in the Different Foods used in these Rations.

	Protein.	Fat.	Carbohydrates.	
			Nit.-free Ex.	Fiber.
	%	%	%	%
Wheat bran, - - - - -	78*	73*	66*	33†
Wheat middlings, - - - - -	79*	85*	83*	33†
Linseed meal, - - - - -	86†	90†	80†	50†
Cotton seed meal, - - - - -	89*	100*	68*	33†
Pea meal, - - - - -	83*	54*	94*	26*
Corn meal, - - - - -	76†	92*	87*	58†
Corn and cob meal, - - - - -	76*	82*	84*	28*
Gluten meal, - - - - -	87*	88*	91*	33†
Malt sprouts, - - - - -	81†	68†	76†	64†
Good quality hay, - - - - -	54*	54*	63*	55*
Poor quality hay, - - - - -	45*	28*	60*	46*
Rowen hay, - - - - -	62†	46†	67†	64†
Corn stalks (stover), - - - - -	52*	52*	64*	66*
Corn silage, - - - - -	46*	80*	67*	67*
Potatoes, - - - - -	44*	13*	91*	—
Turnips, etc., - - - - -	84*	77*	95*	80*

* From results of American digestion experiments.

† From results of German digestion experiments.

In order to show the range of variation from day to day in the feeding of the same herd, the minimum and maximum daily rations per 1,000 pounds live weight are appended to these tables. The size of the rations is here measured by the total energy of the nutrients (protein, fats, etc.) A ration which is large in total energy may have a small amount of a given kind of food or a given kind of nutrients. Hence it sometimes happens that the minimum of one of the nutrients furnished by a certain kind of food in a given ration may be greater than the average of the nutrients in that ration. This is the case with the minimum of the coarse food in ration 1, table 13. The same may happen conversely, in the case of the maximum.

TABLE 14.

Dairy Herd No. 1.—Statistics of Herd, Nov. 30 to Dec. 2, 1892.

Reference No.	Breed.	Age.	Weight.	Months since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Minimum per Day.	Maximum per Day.	Total in 5 Days.	Minimum.	Maximum.	Average.	Minimum per Day.	Maximum per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.	5	800	4	18.4	19.3	94.6	5.7	7.0	6.2	1.05	1.30	5.95
2	R. Gy.	2	865	8	8.2	8.9	42.5	5.5	6.5	6.1	.35	.53	2.54
3	G. Gy.	3	850	6	16.5	18.3	87.0	5.0	5.5	5.3	.87	.95	4.54
4	R. Gy.	3	825	18	10.7	11.4	54.8	5.9	6.8	6.5	.63	.75	3.54
5	R. Gy.	3	850	16	7.6	8.3	40.2	6.1	6.3	6.2	.45	.52	2.47
6	P. Dev.	7	825	6	26.4	29.5	141.5	4.2	4.7	4.5	1.13	1.41	6.47
13	R. Gy.	11	1100	21	11.1	13.2	61.2	4.8	5.6	5.1	.56	.69	3.12
14	P. Ay.	5	875	6	19.2	22.4	105.0	4.6	4.9	4.8	.89	1.10	4.96
15	R. Gy.	7	950	2	24.2	25.0	122.9	4.2	4.7	4.5	1.05	1.14	5.52
16	R. Gy.	3	950	2	19.6	20.1	99.3	4.3	5.0	4.6	.86	1.01	4.60
17	G. Jy.	3	850	3	21.4	23.7	112.4	4.0	5.8	4.7	.86	1.31	5.29
18	R. Gy.	7	1050	16	5.3	6.7	30.5	—	—	—	—	—	—
19	R. Gy.	3	875	18	10.8	12.6	58.9	4.6	5.9	5.1	.50	.71	2.98
20	G. Gy.	3	900	8	12.8	17.2	72.8	6.0	6.4	6.1	.77	1.05	4.54

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Val. (En'gy.)	Protein.	Fat.	Carbohy- drates.	Nutritive Ratio.	Fuel Val. (En'gy.)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Wheat bran, -	2.8	.48	.13	1.53	.23	—	.37	.09	1.07	—	—
Middlings, -	1.6	.29	.10	.80	.16	—	.23	.09	.71	—	—
Linseed meal, -	1.8	.60	.16	.64	.15	—	.54	.15	.75	—	—
Gluten meal, -	2.1	.50	.25	1.03	.11	—	.44	.22	.98	—	—
Total concentrat- ed food, -	8.3	1.87	.64	4.00	.65	14800	1.58	.55	3.51	—	11790
Hay, -	11.0	.84	.34	4.70	3.18	—	.45	.19	4.71	—	—
Oat hay, -	5.3	.44	.14	2.03	1.59	—	.24	.08	2.15	—	—
Ensilage, -	27.3	.52	.22	2.88	1.40	—	.24	.17	2.87	—	—
Total coarse food, -	43.6	1.80	.70	9.61	6.17	35700	.93	.44	9.73	—	21660
Total food, -	51.9	3.67	1.34	13.61	6.82	50500	2.51	.99	13.24	6.2	33450
Minimum per day.											
Concentrated food	4.9	.76	.25	1.66	.26	6000	—	—	—	—	—
Coarse food, -	42.7	2.06	.77	9.76	6.00	36400	—	—	—	—	—
Total, -	47.6	2.82	1.02	11.42	6.26	42400	—	—	—	—	—
Maxim'm per day.											
Concentrated food	10.3	1.03	.57	3.41	.59	11800	—	—	—	—	—
Coarse food -	44.4	3.15	.97	11.36	6.70	43500	—	—	—	—	—
Total, -	54.7	4.18	1.54	14.77	7.29	55300	—	—	—	—	—

TABLE 15.

Dairy Herd No. 2.—Statistics of Herd from Dec. 5 to 9, 1892.

Ref. No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.*
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	5	875	4	20.8	26.2	111.7	3.4	5.0	4.3	.73	1.31	4.88
2	G. Jy.,	7	850	4	20.7	21.8	106.7	4.6	5.2	4.9	.98	1.13	5.20
3	G. Jy.,	6	850	5	20.5	22.2	105.3	5.2	5.9	5.5	1.09	1.31	5.94
5	G. Jy.,	4	900	1	30.7	35.1	165.7	4.1	4.4	4.2	1.26	1.51	6.95
6	G. Jy.,	8	825	7	14.7	17.8	81.7	4.7	5.1	4.9	.74	.85	4.01
8	G. Jy.,	9	900	7	17.1	19.5	91.5	4.9	5.4	5.2	.92	1.05	4.78
9	G. Jy.,	7	900	7	16.9	19.1	92.4	4.4	5.0	4.7	.83	.96	4.43
10	G. Jy.,	4	900	2	24.6	26.5	129.1	4.6	5.7	5.0	1.13	1.51	6.50
11	G. Jy.,	4	850	8	5.1	7.0	30.7	5.1	6.0	5.8	.31	.38	1.78
12	G. Jy.,	4	875	8	11.8	12.6	61.0	6.4	7.0	6.4	.67	.88	3.93
13	G. Jy.,	4	850	4	24.0	26.3	124.1	5.1	5.5	5.4	1.32	1.34	6.64
14	G. Jy.,	6	850	4	15.8	17.7	84.4	5.5	5.8	5.6	.89	1.04	4.81
15	G. Jy.,	8	850	6	19.5	22.7	105.4	5.0	5.4	5.3	1.05	1.23	5.59
16	G. Jy.,	7	825	1	22.5	24.3	118.9	4.1	5.1	4.7	1.00	1.19	5.59
17	G. Jy.,	8	875	10	15.4	17.3	82.3	4.0	4.8	4.5	.62	.80	3.70
18	G. Jy.,	7	900	7	17.0	19.3	91.5	4.4	5.0	4.7	.83	.97	4.35
19	Native,	10	1000	9	21.0	24.1	110.5	3.5	3.9	3.7	.76	.88	4.03
20	G. Jy.,	10	975	2	22.6	25.9	124.6	4.3	4.8	4.6	.97	1.22	5.68

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	N.-free Ext.	Fiber.	F. Val. (En'gy)	Protein.	Fat.	Carbo-hyd's.	Nu. Ratio.	F. Val. (En'gy)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Middlings, -	4.7	.73	.25	2.51	.48	—	.58	.21	2.24	—	—
Gluten meal, -	3.7	1.44	.18	1.69	.06	—	1.25	.16	1.56	—	—
Provender,† -	3.0	.34	.13	2.02	.16	—	.22	.12	1.78	—	—
Total concentrat- ed food, -	11.4	2.51	.56	6.22	.70	19900	2.05	.49	5.58	—	16300
Good hay, -	7.2	.56	.21	3.01	1.97	—	.30	.11	2.98	—	—
Poor hay, -	2.2	.19	.06	.90	.62	—	.09	.01	.83	—	—
Ensilage, -	55.3	.74	.30	5.26	3.41	—	.35	.24	5.80	—	—
Total coarse food,	64.7	1.49	.57	9.17	6.00	33400	.74	.36	9.61	—	20700
Total food, -	76.1	4.00	1.13	15.39	6.70	53300	2.79	.85	15.19	6.1	37000
Minimum per day.											
Concentrated food	10.6	2.19	.50	5.96	.64	18500	—	—	—	—	—
Coarse food, -	57.4	1.17	.44	7.39	4.84	26800	—	—	—	—	—
Total, -	68.0	3.36	.94	13.35	5.48	45300	—	—	—	—	—
Maximum per day.											
Concentrated food	11.8	3.04	.60	5.90	.77	20600	—	—	—	—	—
Coarse food, -	66.2	1.80	.68	10.75	7.06	36500	—	—	—	—	—
Total, -	78.0	4.84	1.28	16.65	7.83	57100	—	—	—	—	—

* Calculated from 4 days' test.

† One part oats and two parts corn.

TABLE 16.

Dairy Herd No. 3.—Statistics of Herd from Dec. 12 to 17, 1892.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Gy.,	7	900	0	25.2	25.9	128.3	3.5	4.3	3.8	.91	1.11	4.93
2	G. Jy.,	7	900	12	14.0	16.1	75.4	5.6	6.3	5.9	.85	.94	4.45
3	R. Jy.,	6	850	13	21.8	25.3	115.0	4.1	5.9	4.8	.91	1.50	5.58
4	P. Jy.,	6	825	2	23.3	25.0	121.2	4.7	5.2	4.9	1.14	1.25	5.99
5	G. Jy.,	2	800	4	12.5	14.1	65.9	5.3	6.2	5.6	.68	.87	3.72
6	G. Jy.,	3	775	1	21.0	22.4	107.7	4.5	5.1	4.7	.97	1.08	5.06
7	G. Jy.,	4	775	17	5.4	9.6	36.4	5.8	7.4	6.3	.40	.58	2.28
8	R. Jy.,	3	800	13	11.5	12.7	60.9	5.8	6.4	6.1	.73	.78	3.74
9	G. Jy.,	5	825	2	25.2	27.1	132.2	4.7	5.1	5.0	1.22	1.37	6.57
10	G. Jy.,	4	750	4	15.7	18.2	85.3	4.6	5.9	5.3	.72	1.07	4.52
11	Native,	7	875	1	25.6	29.8	140.2	3.9	4.5	4.1	1.09	1.20	5.75
12	G. Jy.,	3	775	4	12.0	16.4	69.9	5.2	6.8	5.9	.68	1.03	4.13
13	G. Jy.,	2	650	5	9.5	10.7	51.1	4.0	6.5	5.7	.38	.66	2.94

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value (Energy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	—	Cal.
Cotton seed meal,	4.1	1.78	.38	1.15	.25	—	1.58	.38	.86	—	—
Gluten meal, -	3.1	.55	.30	1.73	.23	—	.48	.26	1.65	—	—
Hominy meal, -	3.5	.38	.28	2.23	.15	—	.33	.23	2.14	—	—
Total concentrat-											
ed food, -	10.7	2.71	.96	5.11	.63	19700	2.39	.87	4.65	—	16770
Hay, -	11.0	.61	.33	4.96	2.94	—	.33	.18	4.74	—	—
Stover, -	9.3	.42	.20	3.86	2.66	—	.22	.10	4.23	—	—
Potatoes, -	7.6	.17	.01	1.28	.04	—	.07	—	1.16	—	—
Total coarse food,	27.9	1.20	.54	10.10	5.64	33800	.62	.28	10.13	—	21180
Total food, -	38.6	3.91	1.50	15.21	6.27	53500	3.01	1.15	14.78	5.7	37950
<i>Minimum per day.</i>											
Concentrated food,	10.7	2.74	.96	5.12	.63	19800	—	—	—	—	—
Coarse food, -	25.8	1.11	.49	9.22	4.99	30600	—	—	—	—	—
Total, -	36.5	3.85	1.45	14.34	5.62	50400	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food,	10.7	2.68	.96	5.20	.62	19800	—	—	—	—	—
Coarse food, -	30.2	1.30	.58	11.06	6.37	37300	—	—	—	—	—
Total, -	40.9	3.98	1.54	16.26	6.99	57100	—	—	—	—	—

TABLE 17.

Dairy Herd No. 4.—Statistics of Herd from Dec. 19 to 24, 1892.

Ref. No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.*	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.*
		Yds.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	5	790	3	11.1	13.1	60.8	5.1	5.4	5.3	.58	.69	3.20
2	G. Jy.,	7	900	2	19.0	22.2	102.6	4.8	5.5	5.0	.91	1.12	5.16
3	G. Jy.,	5	890	1	13.6	16.0	73.5	4.9	5.3	5.1	.68	.82	3.73
4	G. Jy.,	7	850	3	17.7	19.2	91.4	4.1	4.6	4.3	.72	.85	3.90
5	G. Jy.,	6	875	7	14.2	15.7	75.6	5.4	5.8	5.6	.82	.86	4.21
6	G. Jy.,	5	850	1	16.8	17.9	87.8	5.4	6.2	5.7	.94	1.11	5.03
7	G. Jy.,	5	825	4	15.6	19.0	89.1	5.7	6.7	6.2	1.05	1.14	5.46
8	G. Jy.,	2	775	8	10.4	11.1	54.0	5.6	5.8	5.7	.60	.63	3.08
9	G. Jy.,	2	775	7	11.7	15.0	63.3	5.2	5.6	5.4	.63	.78	3.40
10	G. Jy.,	4	875	1	11.2	11.4	56.6	5.7	6.1	5.9	.65	.70	3.23
11	G. Jy.,	8	900	10	9.8	12.5	57.1	6.7	7.1	6.9	.70	.84	3.90
12	G. Jy.,	2	810	7	10.0	13.5	60.5	4.8	5.3	5.1	.53	.66	3.05
13	G. Jy.,	2	600	0	13.2	14.4	69.0	3.6	4.3	4.0	.52	.58	2.75
14	G. Jy.,	2	600	1	12.5	13.5	67.9	4.7	5.4	5.0	.60	.73	3.40
15	G. Jy.,	8	900	2	21.9	24.1	117.4	4.1	4.4	4.2	.97	1.01	4.93
16	R. Jy.,	8	875	1	15.9	16.7	81.6	6.3	6.9	6.6	1.00	1.12	5.35
17	G. Jy.,	2	600	2	10.1	10.9	55.1	4.6	5.4	5.0	.49	.60	2.75
18	G. Jy.,	2	625	4	12.9	13.8	67.4	5.7	5.8	5.8	.74	.81	3.93
19	G. Jy.,	5	725	4	15.5	18.5	85.1	5.1	5.4	5.3	.80	1.00	4.51

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	N-free Ext.	Fiber.	F. Val. (Engy)	Protein.	Fat.	Carbo-hyd's.	Nu. Ratio.	F. Val. (Engy)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
Wheat bran, -	3.7	.62	.18	2.03	.31	—	.48	.13	1.44	—	—
Cotton seed meal, -	1.5	.71	.15	.42	.07	—	.63	.15	.31	—	—
Cob meal, -	5.4	.48	.22	3.82	.16	—	.36	.18	3.24	—	—
Total concentrated food, -	10.6	1.81	.55	6.27	.54	18300	1.47	.46	4.99	—	14000
Hay, -	21.4	1.57	.71	8.90	5.00	—	.85	.39	8.36	—	—
Stover, -	9.1	.57	.15	3.04	2.06	—	.30	.08	3.31	—	—
Total coarse food, -	30.5	2.14	.86	11.94	7.06	43000	1.15	.47	11.67	—	25800
Total food, -	41.1	3.95	1.41	18.21	7.60	61300	2.62	.93	16.66	7.0	39800
Minimum per day.											
Concentrated food, -	9.9	1.75	.51	5.74	.52	17050	—	—	—	—	—
Coarse food, -	29.3	2.05	.82	11.40	6.76	41050	—	—	—	—	—
Total, -	39.2	3.80	1.33	17.14	7.28	58100	—	—	—	—	—
Maximum per day.											
Concentrated food, -	11.2	1.79	.56	6.72	.54	19200	—	—	—	—	—
Coarse food, -	34.0	2.37	.92	13.17	7.85	47400	—	—	—	—	—
Total, -	45.2	4.16	1.48	19.89	8.39	66600	—	—	—	—	—

* Calculated from four days' test.

TABLE 18.

Dairy Herd No. 5.—Statistics of Herd from Dec. 26 to 31, 1892.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	3	700	3	13.6	14.9	71.4	4.2	5.2	4.6	.57	.75	3.23
2	G. Jy.,	3	725	1	24.1	24.8	122.2	3.6	4.3	4.0	.86	1.07	4.83
3	Jy.½Ay.	2	600	1	17.9	20.1	97.4	3.4	4.2	3.7	.64	.82	3.58
4	Native,	2	575	9	10.6	11.4	54.0	4.2	4.8	4.6	.46	.55	2.52
5	Native,	6	800	8	16.3	17.9	84.1	3.8	4.2	4.1	.64	.70	3.44
6	Native,	12	800	3	19.2	21.3	100.0	3.1	3.5	3.3	.61	.70	3.33
7	G. G.,	9	925	2	23.4	25.4	122.6	3.1	4.0	3.7	.78	.99	4.58
8	G. Jy.,	9	875	4	13.8	15.3	70.3	4.8	5.2	4.9	.68	.73	3.47
9	G. Hol.,	6	900	10	14.9	15.9	76.6	4.1	5.0	4.5	.62	.77	3.44
10	G. Hol.,	6	875	9	13.1	15.5	71.9	3.5	4.5	3.9	.52	.65	2.82
11	Native,	10	920	4	10.2	21.8	92.3	3.5	4.8	3.8	.39	.93	3.51
12	Native,	6	850	4	17.2	19.5	90.5	4.2	4.6	4.4	.76	.84	3.95
13	G. Jy.,	8	875	0	31.8	34.9	166.3	3.8	4.2	4.0	1.21	1.46	6.59
14	Native,	6	800	1	24.0	26.7	128.1	3.1	3.5	3.3	.79	.94	4.18
15	G. Ay.,	6	800	2	18.5	22.8	104.7	3.6	4.2	3.9	.72	.91	4.08

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Val. (En'gy)	Protein.	Fat.	Carbohy- drates.	Nutritive Ratio.	Fuel Val. (En'gy)
Grain,* - -	Lbs. 8.2	Lbs. 2.64	Lbs. .88	Lbs. 3.39	Lbs. .31	Cal. 15500	Lbs. 2.20	Lbs. .76	Lbs. 2.64	—	Cal. 12200
Ensilage, - -	33.0	.77	.37	7.32	3.43	—	.35	.30	7.20	—	—
Hay, - - -	13.3	1.13	.36	5.11	3.88	—	.61	.19	5.35	—	—
Total coarse food,	46.3	.90	.73	12.43	7.31	43300	.96	.49	12.55	—	27200
Total food, -	54.5	4.54	1.61	15.82	7.62	58800	3.16	1.25	15.19	5.7	39400
<i>Minimum per day.</i>											
Concentrated food	8.0	2.65	.89	3.42	.31	15600	—	—	—	—	—
Coarse food, -	45.2	1.78	.67	11.39	6.77	39900	—	—	—	—	—
Total food, -	53.2	4.43	1.56	14.81	7.08	55500	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food	8.1	2.63	.87	3.38	.31	15400	—	—	—	—	—
Coarse food, -	53.7	2.12	.82	14.16	8.20	49000	—	—	—	—	—
Total, - - -	61.8	4.75	1.69	17.54	8.51	64400	—	—	—	—	—

* 100 lbs. wheat middlings, 125 lbs. gluten meal, 150 lbs. cotton seed meal.

TABLE 19.

Dairy Herd No. 6.—Statistics of Herd from Jan. 2 to 7, 1893.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	3	740	7	8.6	11.0	51.2	4.9	6.4	5.3	.52	.55	2.71
2	G. Jy.,	3	750	9	5.7	6.7	31.5	4.8	5.4	5.0	.30	.34	1.61
3	P. Jy.,	6	775	11	4.2	6.5	28.2	6.2	9.8	7.2	.34	.43	1.93
4	G. Jy.,	4	775	12	11.4	13.9	62.2	5.8	6.5	6.1	.67	.90	3.79
5	G. Jy.,	9	800	9	12.8	14.8	68.5	5.0	5.7	5.3	.66	.81	3.57
6	G. $\frac{1}{2}$ Sw.	7	825	7	13.7	16.2	73.3	4.5	5.7	5.0	.63	.81	3.65
7	G. $\frac{3}{4}$ Sw.	5	900	2	22.7	26.1	122.7	2.5	4.1	3.5	.57	1.02	4.28
8	R. Sw.	5	1100	7	11.0	11.6	56.3	4.4	4.8	4.7	.48	.55	2.62
9	R. Sw.	9	1050	2	24.4	28.1	133.6	3.0	4.1	3.5	.81	1.14	4.67
10	R. Sw.	11	1100	5	20.2	22.6	107.4	3.7	4.0	3.9	.78	.90	4.15

Pounds of Food and Nutrients per day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Val. (En'gy)	Protein.	Fat.	Carbohy- drates.	Nutritive Ratio.	Fuel Val. (En'gy)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Corn meal, - -	3.7	.37	.16	2.66	.04	—	.21	.15	2.33	—	—
Wheat middlings,	2.0	.38	.12	1.05	.13	—	.30	.10	.91	—	—
Cotton seed meal,	1.8	.81	.26	.48	.03	—	.72	.26	.34	—	—
Total concentrat- ed food, - -	7.5	1.56	.54	4.19	.20	13400	1.23	.51	3.58	—	11100
Oat hay, - -	4.7	.26	.13	2.06	1.35	—	.14	.07	2.04	—	—
Hay, - -	14.4	.88	.41	6.43	3.83	—	.48	.23	6.16	—	—
Stover, - -	7.5	.35	.12	2.55	1.72	—	.18	.06	2.77	—	—
Total coarse food,	26.6	1.49	.67	11.04	6.90	38900	.80	.36	10.97	—	23400
Total food, -	34.1	3.05	1.21	15.23	7.10	52300	2.03	.87	14.55	8.1	34500
<i>Minimum per day.</i>											
Concentrated food	7.4	1.56	.55	4.06	.22	13200	—	—	—	—	—
Coarse food, -	25.6	1.44	.64	10.72	6.70	37800	—	—	—	—	—
Total, - -	33.0	3.00	1.19	14.78	6.92	51000	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food	7.5	1.38	.49	4.32	.20	13050	—	—	—	—	—
Coarse food, -	29.2	1.62	.71	11.95	7.49	42150	—	—	—	—	—
Total, - -	36.7	3.00	1.20	16.27	7.69	55200	—	—	—	—	—

TABLE 20.

Dairy Herd No. 7.—Statistics of Herd from Jan. 9 to 14, 1893.

Ref. No.	Breed.	Age.	Weight.	Months since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Hol.,	7	850	7	21.6	22.9	111.5	4.3	4.5	4.4	.94	.99	4.86
2	G. Dev.,	8	900	4	25.0	26.2	127.3	3.5	4.3	3.8	.90	1.08	4.84
3	G. Hol.,	3	850	5	24.7	28.1	131.3	2.9	3.3	3.0	.72	8.7	3.99
4	G. Hol.,	4	825	2	21.3	24.0	111.8	4.0	4.3	4.1	.86	1.03	4.57
5	G. Jy.,	8	925	6	13.8	14.8	70.6	5.7	5.9	5.8	.80	.84	4.07
6	G. Jy.,	8	775	2	14.8	17.0	81.2	6.4	6.8	6.6	1.01	1.09	5.36
7	G. Jy.,	5	650	1	21.4	22.8	109.7	4.5	5.1	4.8	.98	1.16	5.27
8	G. Jy.,	5	750	9	18.3	18.9	92.9	4.7	5.3	5.1	.89	.99	4.73
9	G. Hol.,	7	925	5	23.2	24.2	119.2	4.3	5.0	4.7	1.00	1.19	5.60
10	G. Ay.,	7	850	6	15.6	16.7	81.7	4.4	4.8	4.6	.72	.79	3.77
11	G. Jy.,	2	700	3	25.9	27.2	132.4	3.4	3.5	3.4	.88	.95	4.56
12	G. Jy.,	5	850	9	13.3	14.3	69.2	6.3	6.8	6.6	.87	.94	4.55
13	Native,	9	825	4	20.2	22.5	106.6	3.3	4.5	4.1	.74	.96	4.34
14	G. Ay.,	8	800	8	16.9	17.7	86.2	5.4	6.1	5.7	.94	1.03	4.96
15	G. Hol.,	5	900	7	17.2	17.8	85.2	4.0	4.4	4.2	.69	.76	3.59
16	Native,	7	850	9	25.9	27.5	132.7	3.5	4.1	3.8	.92	1.06	4.98
17	Native,	7	850	9	16.5	17.3	84.5	3.9	5.3	4.9	.65	.89	4.15

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value (Energy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Provender,*	8.5	.83	.38	5.95	.21	—	.54	.34	5.10	—	—
Wheat middlings,	5.6	1.14	.36	3.01	.30	—	.90	.31	2.60	—	—
Concentrated food	14.1	1.97	.74	8.96	.51	24400	1.44	.65	7.70	—	19740
Hay, - - -	24.4	1.86	.81	11.23	5.87	38700	1.00	.44	10.30	—	22860
Total food, -	38.5	3.83	1.55	20.19	6.38	63100	2.44	1.09	18.00	8.4	42600
<i>Minimum per day.</i>											
Concentrated food	13.8	1.93	.73	8.83	.50	24050	—	—	—	—	—
Coarse food, -	23.9	1.82	.78	10.97	5.73	37750	—	—	—	—	—
Total, - - -	37.7	3.75	1.51	19.80	6.23	61800	—	—	—	—	—
<i>Maximum per day.</i>											
Concentrated food	13.8	2.00	.75	8.99	.51	24500	—	—	—	—	—
Coarse food, -	25.0	1.89	.82	11.48	6.00	39500	—	—	—	—	—
Total, - - -	38.8	3.89	1.57	20.47	6.51	64000	—	—	—	—	—

* Said to be one-third oats and two-thirds corn.

TABLE 21.

Dairy Herd No. 8.—Statistics of Herd from Jan. 16 to 21, 1893.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Minimum.	Maximum.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Gy.,	8	850	5	16.3	18.6	87.6	4.1	5.7	4.9	.72	1.03	4.26
2	R. Gy.,	4	750	3	14.1	16.0	75.6	4.9	5.6	5.2	.72	.86	3.98
3	R. Gy.,	4	600	4	11.7	14.0	63.8	4.7	5.6	5.2	.55	.72	3.33
4	R. Gy.,	3	700	11	6.8	8.0	38.0	4.3	6.0	5.5	.34	.48	2.09
5	R. Gy.,	2	525	0	17.7	18.6	90.4	4.3	5.2	4.7	.76	.95	4.25
6	G. Gy.,	5	750	2	24.1	26.0	126.2	4.0	4.3	4.2	.99	1.08	5.26
7	G. Gy.,	3	700	2	17.3	19.8	93.4	4.2	4.7	4.5	.81	.91	4.22
8	R. Gy.,	7	750	2	13.9	16.4	78.3	3.9	5.1	4.5	.63	.84	3.49
9	G. Gy.,	10	850	4	13.5	14.6	69.6	4.9	5.2	5.0	.62	.73	3.42
10	G. Gy.,	7	850	1	23.3	26.9	124.8	3.5	4.9	4.2	.98	1.20	5.29
11	G. Gy.,	5	700	2	15.1	17.0	80.5	4.5	5.0	4.8	.68	.83	3.87
12	Native,	13	900	2	24.1	26.2	127.0	4.2	4.5	4.3	1.04	1.16	5.50

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value (Energy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lb	Lbs.		Cal.
Grain,* - -	12.2	2.08	.64	6.47	1.23	20900	1.60	.50	5.35	—	15050
Hay, - - -	28.7	2.98	.79	11.75	7.74	45100	1.56	.43	11.60	—	26300
Total food, -	40.9	5.06	1.43	18.22	8.97	66000	3.16	.93	16.95	6.0	41350
<i>Minimum per day.</i>											
Concentrated food	11.8	2.02	.62	6.26	1.19	20250	—	—	—	—	—
Coarse food, -	23.5	2.44	.65	9.64	6.36	37050	—	—	—	—	—
Total, - - -	35.3	4.46	1.27	15.90	7.55	57300	—	—	—	—	—
<i>Maximum per day.</i>											
Concentrated food	12.7	2.16	.66	6.73	1.28	21700	—	—	—	—	—
Coarse food, -	34.6	3.59	.95	14.17	9.34	54400	—	—	—	—	—
Total, - - -	47.3	5.75	1.61	20.90	10.62	76100	—	—	—	—	—

* Grain consisted of: Wheat bran, 200 lbs.; cob meal, 300 lbs.

TABLE 22.

Dairy Herd No. 9.—Statistics of Herd from Jan. 23 to 28, 1893.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per day.	Max. per day.	Total in 5 Days.	Min.	Max.	Average.	Min. per day.	Max. per day.	Total in 5 days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	R. Gy.,	11	925	4	16.0	16.8	82.7	4.3	4.5	4.4	.72	.76	3.66
2	G. Gy.,	9	900	3	23.0	24.1	117.4	3.5	4.1	3.8	.82	.99	4.51
3	G. Gy.,	10	900	3	17.5	19.4	93.9	4.4	4.6	4.5	.81	.89	4.26
4	R. Gy.,	8	925	2	18.9	19.5	96.4	5.2	5.6	5.3	.99	1.09	5.16
5	Native,	13	1000	10	16.0	18.5	85.6	4.4	4.5	4.4	.72	.83	3.80
6	R. Gy.,	4	800	2	13.9	15.0	71.7	3.8	4.1	4.0	.54	.60	2.86
7	R. Gy.,	5	850	2	10.3	11.0	53.0	5.4	5.8	5.5	.56	.61	2.93
8	G. Gy.,	6	800	10	12.1	12.8	62.3	5.0	5.4	5.2	.62	.69	3.26
9	G. Gy.,	4	925	8	13.7	15.0	71.7	4.6	5.0	4.9	.65	.74	3.50
10	G. Gy.,	5	900	4	5.1	5.9	28.4	4.8	5.2	4.9	.26	.30	1.41
11	R. Gy.,	6	825	3	10.6	11.3	54.8	4.4	5.5	4.9	.49	.61	2.71
12	G. Gy.,	5	900	3	15.9	17.8	84.5	4.9	5.6	5.1	.80	.97	4.34

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value (Energy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Grain,* - -	7.4	1.62	.65	3.81	.22	13240	1.20	.58	3.14	—	10500
Hay, - - -	12.0	.72	.24	4.75	3.16	—	.39	.13	4.73	—	—
Rowen, - -	5.1	.64	.18	1.78	1.08	—	.40	.08	1.89	—	—
Stover, - -	5.1	.32	.07	2.15	1.38	—	.17	.04	2.29	—	—
Total coarse food,	22.2	1.68	.49	8.68	5.62	31760	.96	.25	8.91	—	19450
Total food, -	29.6	3.30	1.14	12.49	5.84	45000	2.16	.83	12.05	6.4	29950
<i>Minimum per day.</i>											
Concentrated food	6.6	1.46	.58	3.43	.20	11900	—	—	—	—	—
Coarse food, -	20.1	1.56	.46	7.85	5.08	28900	—	—	—	—	—
Total, - - -	26.7	3.02	1.04	11.28	5.28	40800	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food	7.7	1.68	.67	3.95	.23	13700	—	—	—	—	—
Coarse food, -	23.4	1.77	.51	9.22	5.97	33700	—	—	—	—	—
Total, - - -	31.1	3.45	1.18	13.17	6.20	47400	—	—	—	—	—

*Grain mixture consisted of 300 lbs. corn meal, 150 lbs. wheat bran, 150 lbs. cotton seed meal, and 150 lbs. cream gluten.

TABLE 23.

Dairy Herd No. 10.—Statistics of Herd from Jan. 30 to Feb. 4, 1893.

Ref. No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per day.	Max. per day.	Total in 5 Days.	Min.	Max.	Average.	Min. per day.	Max. per day.	Total in 5 days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	7	825	9	11.5	13.2	62.5	4.9	5.5	5.3	.62	.71	3.32
2	G. Jy.,	8	875	7	12.2	13.7	65.7	5.9	6.2	6.1	.74	.84	3.99
3	G. Jy.,	6	875	—	14.3	15.7	75.8	4.2	4.6	4.4	.63	.70	3.33
4	G. Jy.,	3	800	0	15.0	17.4	78.5	4.7	5.6	5.1	.71	.89	3.97
5	P. Jy.,	8	925	0	25.9	28.2	135.1	4.7	5.3	5.0	1.26	1.41	6.72
6	G. Jy.,	4	800	4	17.4	18.5	90.2	4.0	4.4	4.3	.74	.80	3.85
7	G. Jy.,	6	975	0	36.8	38.8	189.5	3.8	4.2	3.9	1.44	1.55	7.39
8	G. Dev.	8	900	1	21.6	23.1	112.6	3.9	4.5	4.2	.90	1.04	4.73
9	G. Jy.,	5	875	0	26.6	28.5	137.9	4.8	5.4	5.1	1.38	1.49	7.07
10	G. Jy.,	5	850	2	21.9	24.3	116.5	4.7	5.3	4.9	1.05	1.19	5.70
11	G. Jy.,	5	825	2	19.4	20.6	100.5	4.0	4.3	4.1	.80	.89	4.15
12	G. Jy.,	3	775	4	9.1	13.2	59.1	5.9	6.6	6.1	.60	.79	3.60
13	R. Jy.,	3	800	3	13.3	15.9	76.2	4.9	6.5	5.5	.77	.86	4.12
14	R. Jy.,	3	825	0	30.7	34.9	163.5	3.5	3.6	3.5	1.10	1.22	5.76
15	R. Jy.,	2	800	2	12.3	15.2	71.8	3.9	4.4	4.1	.54	.65	2.97
16	G. Jy.,	5	850	0	25.9	28.1	136.2	4.5	5.1	4.7	1.19	1.38	6.42
17	G. Jy.,	6	800	4	17.9	19.0	91.5	4.5	5.1	4.8	.81	.91	4.38
18	G. Jy.,	6	825	4	19.3	19.8	98.1	4.5	4.6	4.6	.89	.91	4.48

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Val. (En'gy).	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Val. (En'gy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Grain,*	8.2	1.57	.55	4.62	.27	14300	1.09	.50	3.72	—	11100
Stover,	6.9	.33	.14	2.85	1.92	—	.17	.08	3.09	—	—
Rowen,	10.2	1.31	.35	4.05	2.25	—	.81	.16	4.15	—	—
Hay,	5.2	.47	.18	2.26	1.30	—	.25	.10	2.08	—	—
Total coarse food,	22.3	2.11	.67	9.16	5.47	34000	1.23	.34	9.32	—	21000
Total food,	30.5	3.68	1.22	13.78	5.74	48300	2.32	8.4	13.04	6.4	32100
<i>Minimum per day.</i>											
Concentrated food	8.1	1.56	.55	4.60	.27	14200	—	—	—	—	—
Coarse food,	20.6	1.96	.61	8.44	5.01	31200	—	—	—	—	—
Total,	28.7	3.52	1.16	13.04	5.28	45400	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food	8.0	1.54	.54	4.52	.26	14050	—	—	—	—	—
Coarse food,	26.4	2.50	.79	10.85	6.43	40150	—	—	—	—	—
Total,	34.4	4.04	1.33	15.37	6.69	54200	—	—	—	—	—

* Grain mixtures consisted of 600 lbs. corn meal, 300 lbs. cotton seed meal, and 170 lbs. wheat bran.

TABLE 24.

Dairy Herd No. 11.—Statistics of Herd from Feb. 6 to 11, 1893.

Ref. No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	3	875	5	15.9	19.9	89.3	4.8	5.6	5.2	.89	.96	4.67
2	G. Jy.,	4	850	5	14.8	17.2	80.1	5.5	5.8	5.7	.86	.95	4.57
3	G. Jy.,	5	875	5	16.7	20.3	93.8	4.3	4.7	4.5	.79	.87	4.23
4	G. Jy.,	4	850	5	18.1	19.1	92.6	4.4	5.0	4.8	.80	.95	4.50
5	G. Jy.,	4	900	5	18.9	21.5	101.8	4.7	5.1	4.9	.95	1.03	4.93
6	G. Jy.,	3	825	5	13.3	16.6	77.2	4.2	4.7	4.4	.63	.71	3.39
7	G. Jy.,	3	850	5	12.0	13.8	66.0	4.2	4.7	4.4	.55	.61	2.89
8	G. Jy.,	7	825	5	16.0	18.2	86.1	5.2	5.9	5.6	.93	1.01	4.79
9	G. Jy.,	4	850	5	17.2	18.8	91.2	5.6	6.2	6.0	1.04	1.15	5.46
10	G. Jy.,	10	1050	5	12.0	14.0	65.6	4.3	5.2	4.7	.58	.65	3.09
11	G. Jy.,	4	800	5	13.7	15.6	73.9	5.3	5.7	5.5	.77	.84	4.05
12	G. Jy.,	4	800	5	6.2	6.7	31.9	4.5	5.6	4.8	.29	.35	1.53
13	G. Jy.,	4	850	5	17.6	19.5	93.5	4.2	4.9	4.5	.82	.88	4.24
14	G. Jy.,	8	900	5	12.5	15.5	69.8	4.7	5.6	5.2	.70	.75	3.63
15	G. Jy.,	8	925	5	16.2	18.5	88.5	4.8	5.3	5.0	.79	.97	4.43
16	G. Jy.,	2	825	5	12.0	13.9	62.6	4.8	5.3	5.0	.57	.69	3.16
17	G. Jy.,	2	875	5	12.0	13.3	63.7	4.1	4.6	4.4	.49	.59	2.80
18	G. Jy.,	2	875	5	13.9	16.9	76.4	4.1	4.4	4.3	.60	.70	3.28

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	N.-free Ext.	Fiber.	F. Val. (En'gy)	Protein.	Fat.	Carbo-hyd's.	Nu. Ratio.	F. Val. (En'gy)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Grain,* - -	10.2	2.51	.78	5.20	.43	18400	1.91	.70	4.17	—	14250
Hay, - - -	12.1	.83	.28	4.61	4.21	—	.45	.15	5.22	—	—
Oat hay, - -	6.7	.57	.22	2.85	1.01	—	.31	.12	2.35	—	—
Stover, - -	3.8	.18	.07	1.52	1.13	—	.09	.04	1.72	—	—
Total coarse food,	22.6	1.58	.57	8.98	6.35	33900	.85	.31	9.29	—	20200
Total food, -	32.8	4.09	1.35	14.18	6.78	52300	2.76	1.01	13.46	5.7	34450
<i>Minimum per day.</i>											
Concentrated food,	10.4	2.53	.79	5.35	.44	18800	—	—	—	—	—
Coarse food, -	19.9	1.39	.50	7.93	5.61	29900	—	—	—	—	—
Total, - - -	30.3	3.92	1.29	13.28	6.05	48700	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food,	10.2	2.64	.80	5.11	.42	18550	—	—	—	—	—
Coarse food, -	23.8	1.64	.59	9.43	6.82	35750	—	—	—	—	—
Total, - - -	34.0	4.28	1.39	14.54	7.24	54300	—	—	—	—	—

* Grain mixture consisted of 200 lbs. wheat middlings, 200 lbs. corn meal, 200 lbs. cotton seed meal, 50 lbs. wheat bran.

TABLE 25.

Dairy Herd No. 12.—Statistics of Herd from Feb. 13 to 18, 1893.

Ref. No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	Native,	3	850	2	24.1	26.0	124.0	3.9	5.2	4.6	.90	1.31	5.69
2	Native,	6	875	2	31.3	32.8	160.9	3.8	4.4	4.0	1.19	1.44	6.47
3	G. Jy.,	4	850	11	13.8	14.6	70.5	4.8	5.4	5.1	.66	.75	3.61
4	R. Jy.,	4	775	6	16.2	18.7	85.1	4.7	5.9	5.1	.78	1.10	4.38
5	G. Jy.,	3	800	13	14.0	15.3	73.5	6.2	6.9	6.5	.90	1.00	4.78
6	G. Jy.,	9	850	13	14.1	15.3	73.9	5.3	5.5	5.4	.75	.84	3.94
7	G. Jy.,	6	825	2	27.8	29.4	143.0	4.4	4.9	4.7	1.25	1.40	6.66
8	Native,	8	850	1	40.0	41.3	203.6	3.6	4.3	4.0	1.49	1.72	8.06
9	Native,	5	875	6	21.8	26.8	117.2	3.8	5.2	4.6	.83	1.26	5.40
10	R. Hol.,	2	750	6	19.2	22.8	104.6	3.0	3.4	3.2	.63	.69	3.32
11	Native,	3	825	13	11.2	11.9	57.1	4.5	5.2	4.9	.54	.58	2.81
12	Native,	6	875	9	10.6	11.6	54.4	4.1	4.5	4.3	.44	.49	2.33
13	G. Jy.,	8	925	11	14.7	16.0	76.7	4.5	4.9	4.7	.69	.75	3.58
14	G. Jy.,	6	850	13	22.9	27.5	124.4	4.6	5.2	4.9	1.10	1.43	6.14
15	R. Hol.,	8	1100	8	30.6	31.9	156.0	3.2	3.5	3.3	.98	1.12	5.15
16	G. Jy.,	6	850	4	16.4	18.0	86.6	4.3	4.5	4.4	.72	.78	3.78
17	R. Hol.,	4	1025	6	24.3	26.1	126.3	3.0	4.1	3.6	.76	1.02	4.59
18	G. Jy.,	8	800	10	9.3	12.6	53.0	4.3	4.8	4.6	.44	.61	2.45
19	Native,	8	1100	4	20.0	21.4	103.0	3.2	4.2	3.9	.68	.87	3.98
20	G. Jy.,	5	875	3	29.2	33.1	155.8	4.0	4.2	4.1	1.17	1.39	6.36

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	N.-free Ext.	Fiber.	F. Val. (En'gy)	Protein.	Fat.	Carbo-hyd's.	Nu. Ratio.	F. Val. (En'gy)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Wheat bran, -	3.8	.56	.21	2.11	.35	—	.44	.15	1.48	—	—
Grain,* -	4.7	1.25	.36	2.27	.12	—	.93	.35	1.80	—	—
Malt sprouts, -	4.6	1.15	.09	2.02	.56	—	.92	.06	1.56	—	—
Total concentrated food, -	13.1	2.96	.66	6.40	1.03	22100	2.29	.56	4.84	—	15650
Ensilage, -	41.1	.71	.29	3.12	2.18	—	.33	.23	3.55	—	—
Hay, -	7.4	.69	.28	3.26	1.77	—	.37	.15	3.02	—	—
Total coarse food, -	48.5	1.40	.57	6.38	3.95	24200	.70	.38	6.57	—	15100
Total food, -	61.6	4.36	1.23	12.78	4.98	46300	2.99	.94	11.41	4.5	30750
Minimum per day.											
Concentrated food	12.7	2.91	.64	6.28	1.03	21700	—	—	—	—	—
Coarse food, -	48.2	1.37	.55	6.21	3.86	23600	—	—	—	—	—
Total, -	60.9	4.28	1.19	12.49	4.89	45300	—	—	—	—	—
Maximum per day.											
Concentrated food	13.3	2.98	.67	6.57	1.08	22600	—	—	—	—	—
Coarse food, -	50.3	1.56	.63	7.19	4.39	27100	—	—	—	—	—
Total, -	63.6	4.54	1.30	13.76	5.47	49700	—	—	—	—	—

* Grain mixture consisted of equal parts, by weight, of corn meal and cotton seed meal.

TABLE 26.

Dairy Herd No.13.—Statistics of Herd from Feb. 27 to Mar. 4, 1893.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	P. Jy.,	3	750	10	12.6	13.5	65.2	4.5	5.1	4.9	.58	.69	3.20
2	P. Jy.,	2	700	5	16.0	17.4	83.6	4.1	4.7	4.4	.66	.82	3.68
3	G. Jy.,	3	700	12	11.6	12.7	60.8	4.4	4.6	4.5	.53	.59	2.77
4	G. Jy.,	3	700	3	20.9	21.7	107.2	3.8	4.6	4.2	.83	1.00	4.47
5	P. Jy.,	3	700	9	11.8	12.6	60.9	4.1	4.9	4.5	.49	.60	2.75
6	P. Jy.,	3	700	10	12.6	14.4	67.7	4.9	5.3	5.1	.66	.71	3.45
7	P. Jy.,	2	700	7	12.5	13.2	63.7	5.0	6.0	5.5	.63	.77	3.53
8	G. Jy.,	7	725	10	8.1	8.6	41.2	4.7	5.0	4.8	.38	.43	1.98
9	R. Jy.,	10	850	10	10.5	11.1	53.9	5.2	6.0	5.6	.58	.65	3.01
10	G. Hol.,	10	850	2	20.8	23.1	109.8	3.2	3.7	3.4	.67	.84	3.73
11	G. Dev.,	10	850	14	6.5	7.5	36.0	5.4	5.9	5.6	.35	.44	2.01
12	G. Jy.,	4	825	1	20.0	21.3	104.2	3.9	4.3	4.1	.80	.91	4.29
13	G. Dev.,	7	875	26	11.0	13.5	58.3	3.8	4.3	4.1	.43	.51	2.36
14	G. Ay.,	5	850	12	6.9	9.2	39.0	4.8	5.1	4.9	.35	.44	1.90
15	G. Jy.,	6	850	7	10.9	12.8	58.0	4.9	5.3	5.0	.54	.64	2.92
16	G. Gy.,	7	850	8	8.7	11.5	48.6	5.0	5.5	5.3	.44	.59	2.57
17	Native,	6	925	14	11.1	12.2	58.4	4.0	4.9	4.3	.46	.60	2.50
18	G. Dev.,	10	875	12	10.2	12.1	56.3	4.9	5.4	5.1	.53	.63	2.87
19	G. Jy.,	3	775	10	7.0	.83	37.6	5.5	5.9	5.7	.39	.48	2.16

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value (Energy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	—	Cal.
Grain,*	11.2	2.25	.72	6.13	.56	19600	1.67	.64	5.27	—	15600
Ensilage,	30.7	.33	.20	2.69	1.39	—	.15	.16	2.73	—	—
Hay,	7.5	.70	.22	3.28	1.99	—	.38	.12	3.17	—	—
Total coarse food,	38.2	1.03	.42	5.97	3.38	21100	.53	.28	5.90	—	13150
Total food,	49.4	3.28	1.14	12.10	3.94	40700	2.20	.92	11.17	6.0	28750
<i>Minimum per day.</i>											
Concentrated food,	11.0	2.23	.72	6.08	.55	19500	—	—	—	—	—
Coarse food,	37.0	1.01	.41	5.80	3.29	20500	—	—	—	—	—
Total,	48.0	3.24	1.13	11.88	3.84	40000	—	—	—	—	—
<i>Maxim'm per day.</i>											
Concentrated food,	11.1	2.26	.72	6.15	.57	19800	—	—	—	—	—
Coarse food,	40.1	1.05	.43	6.15	3.47	21600	—	—	—	—	—
Total,	51.2	3.31	1.15	12.30	4.04	41400	—	—	—	—	—

* Grain mixture consisted of 50 lbs. cotton seed meal, 200 lbs. wheat middlings, and 100 lbs. corn meal.

TABLE 27.

Dairy Herd No. 14.—Statistics of Herd from March 6 to 11, 1893.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	2	800	3	19.8	20.8	81.8	4.8	4.9	4.8	.95	1.02	3.95
2	G. Jy.,	2	800	2	21.1	22.9	88.2	5.1	5.9	5.3	1.10	1.27	4.75
3	G. Jy.,	2	775	3	21.6	22.9	89.1	4.9	5.2	5.0	1.07	1.19	4.52
4	G. Jy.,	6	825	5	16.1	17.1	66.6	5.1	5.5	5.4	.82	.94	3.58
5	G. Jy.,	8	850	11	10.1	11.7	43.1	6.3	6.5	6.4	.64	.76	2.75
6	G. Jy.,	10	850	5	19.6	20.8	81.6	4.7	4.9	4.9	.96	1.02	3.96
7	G. Jy.,	9	900	3	29.3	34.2	127.3	3.6	4.7	4.0	1.10	1.40	5.12
8	G. Jy.,	9	950	3	28.4	31.3	118.7	4.2	5.1	4.5	1.22	1.52	5.43
9	G. Jy.,	8	950	1	34.0	36.9	139.5	4.9	5.1	5.0	1.67	1.88	6.98
10	G. Jy.,	17	950	5	19.9	23.0	87.7	3.7	4.2	3.9	.74	.96	3.38

Pounds of Food and Nutrients per day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.						DIGESTED NUTRIENTS AND ENERGY.					
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Val. (En'gy).		Protein.	Fat.	Carbohy- drates.	Nutritive Ratio.	Fuel Val. (En'gy).	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.		Lbs.	Lbs.	Lbs.		Cal.	
Grain,* - -	9.4	2.23	.85	4.95	.38	17690		1.71	.64	3.79	—	12900	
Hay, - - -	18.7	1.60	.68	8.00	4.33	—		.86	.37	7.42	—	—	
Stover, - -	3.6	.17	.08	1.77	1.14	—		.09	.04	1.88	—	—	
Total coarse food,	22.3	1.77	.76	9.77	5.47	34810		.95	.41	9.30	—	20850	
Total food, -	31.7	4.00	1.61	14.72	5.85	52500		2.66	1.05	13.09	5.8	33750	
<i>Minimum per day.</i>													
Concentrated food	9.4	2.22	.85	4.92	.38	17600		—	—	—	—	—	
Coarse food, -	20.2	1.61	.68	8.86	4.97	31600		—	—	—	—	—	
Total, - - -	29.6	3.83	1.53	13.78	5.35	49200		—	—	—	—	—	
<i>Maxim'm per day.</i>													
Concentrated food	9.7	2.30	.87	5.10	.40	18200		—	—	—	—	—	
Coarse food, -	22.9	1.82	.79	10.01	5.59	35700		—	—	—	—	—	
Total, - - -	32.6	4.12	1.66	15.11	5.99	53900		—	—	—	—	—	

* Grain mixture consisted of 100 lbs. gluten meal, 100 lbs. oat feed, 100 lbs. wheat bran.

TABLE 28.

Dairy Herd No. 15.—Statistics of Herd from March 13 to 18, 1893.

Ref. No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Min. per Day.	Max. per Day.	Total in 5 Days.	Min.	Max.	Average.	Min. per Day.	Max. per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	6	850	1	18.4	19.2	93.6	4.0	4.5	4.3	.73	.86	4.04
2	G. Jy.,	5	825	7	10.6	11.6	56.4	3.4	3.8	3.6	.36	.43	2.04
3	G. Jy.,	5	850	4	13.6	14.7	70.0	5.4	5.8	5.6	.75	.85	3.95
4	G. Ay.,	5	875	1	20.3	21.5	105.2	3.5	4.0	3.8	.75	.81	3.94
5	G. Jy.,	5	850	2	18.8	20.8	99.0	4.1	4.9	4.6	.85	.98	4.52
6	G. Jy.,	9	850	6	13.2	14.2	68.8	5.3	5.7	5.5	.73	.79	3.78
7	G. Jy.,	5	800	2	9.7	10.7	50.1	7.5	7.7	7.6	.74	.82	3.82
8	G. Jy.,	9	860	6	12.8	13.3	65.1	4.9	5.3	5.1	.65	.68	3.31
9	G. Jy.,	9	875	7	11.3	12.5	59.0	5.9	6.3	6.1	.68	.79	3.61
10	G. Jy.,	5	875	6	10.3	12.4	57.8	5.2	6.6	5.7	.57	.82	3.34
11	G. Jy.,	4	850	5	12.1	12.6	61.5	4.6	5.0	4.8	.57	.62	2.98
12	G. Jy.,	5	875	5	13.1	13.7	67.2	4.8	5.3	5.0	.63	.71	3.37
13	G. Jy.,	4	875	3	12.7	13.9	66.2	4.7	5.3	5.0	.60	.70	3.28
14	G. Jy.,	8	850	2	18.6	21.3	99.2	3.2	3.7	3.4	.65	.70	3.39
15	G. Jy.,	8	825	8	11.0	11.4	56.3	5.0	5.5	5.3	.57	.62	2.97
16	G. Jy.,	4	825	8	9.4	9.8	48.0	5.6	6.0	5.7	.53	.60	2.81
17	G. Jy.,	4	835	7	12.3	13.1	63.9	4.2	4.8	4.5	.52	.61	2.87
18	G. Jy.,	4	800	7	10.8	11.8	55.2	4.6	5.4	4.9	.50	.59	2.72
19	G. Jy.,	4	800	7	9.2	10.0	48.0	5.4	5.9	5.7	.50	.57	2.71

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Val. (Engy).	Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Val. (Engy).
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	—	Cal.
Grain,*	8.8	.92	.46	5.82	.28	15000	.70	.37	4.79	—	11800
Fodder,†	14.9	.81	.26	6.67	4.14	—	.43	.14	6.80	—	—
Hay,	5.4	.40	.10	2.57	1.41	—	.22	.05	2.40	—	—
Total coarse food,	20.3	1.21	.36	9.24	5.55	31300	.65	.19	9.20	—	19100
Total food,	29.1	2.13	.82	15.06	5.83	46300	1.35	.56	13.99	11.3	30900
Minimum per day.											
Concentrated food	8.0	.83	.41	5.33	.26	13650	—	—	—	—	—
Coarse food,	17.3	1.02	.31	7.86	4.74	26650	—	—	—	—	—
Total,	25.3	1.85	.72	13.19	5.00	40300	—	—	—	—	—
Maximum per day.											
Concentrated food	9.5	.98	.48	6.29	.30	16100	—	—	—	—	—
Coarse food,	23.2	1.57	.46	10.87	6.22	36700	—	—	—	—	—
Total,	32.7	2.55	.94	17.16	6.52	52800	—	—	—	—	—

* Grain mixture consisted of 1000 lbs. cob meal, 175 lbs. rye meal, 150 lbs. wheat bran, 100 lbs. oat feed, and 100 lbs. O. P. linseed.

† Fodder consisted of 300 lbs. hay, and 400 lbs. stover.

TABLE 29.

Dairy Herd No. 16.—Statistics of Herd, March. 20 to 25, 1893.

Reference No.	Breed.	Age.	Weight.	Months Since Last Calf.	MILK FLOW.			DAILY PERCENT-AGE OF FAT.			YIELD OF FAT.		
					Minimum per Day.	Maximum per Day.	Total in 5 Days.	Minimum.	Maximum.	Average.	Minimum per Day.	Maximum per Day.	Total in 5 Days.
		Yrs.	Lbs.	Mo.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Dev.	7	1050	7	16.9	18.6	87.8	3.8	4.3	4.0	.66	.75	3.55
2	G. Dev.	5	1000	7	11.0	12.5	57.6	3.9	5.2	4.4	.44	.58	2.56
3	G. Dev.	5	900	7	14.1	16.4	75.5	4.2	4.8	4.6	.59	.78	3.44
4	G. Jy.	12	1100	7	18.6	20.0	96.8	4.3	4.7	4.5	.84	.92	4.38
5	G. Dev.	5	1035	7	14.6	15.4	74.7	4.1	4.5	4.2	.61	.67	3.16
6	Native,	4	850	6	14.8	18.2	78.2	4.4	4.8	4.7	.71	.80	3.64
7	G. Dev.	7	875	7	20.0	21.7	103.9	4.2	4.7	4.5	.84	.98	4.67
8	G. Dev.	7	875	7	12.0	12.0	61.7	4.2	4.9	4.5	.52	.63	2.79
9	G. Gy.	4	875	10	14.6	15.3	75.7	4.3	5.1	4.8	.66	.78	3.60
10	G. Dev.	4	875	7	12.9	13.5	65.7	4.2	4.8	4.4	.54	.65	2.90
11	Native,	5	850	8	26.1	28.3	134.4	4.4	4.8	4.5	1.15	1.29	6.10
12	G. Jy.	7	825	6	13.5	15.0	70.3	5.6	5.9	5.7	.77	.87	4.05
13	Native,	5	775	9	13.4	13.9	68.0	4.0	4.8	4.5	.55	.65	3.06
14	G. Jy.	8	800	11	14.2	16.0	75.5	4.9	5.9	5.3	.70	.88	3.98
15	G. Hol.,	6	940	3	23.5	24.2	119.6	3.5	4.1	3.7	.82	.99	4.44
16	G. Jy.	5	850	4	14.8	15.2	75.0	4.2	5.4	5.0	.63	.81	3.74
17	G. Gy.	3	825	4	17.3	18.8	88.9	4.1	4.7	4.5	.71	.88	3.97
18	G. Gy.	5	850	6	13.7	14.4	70.8	5.3	5.8	5.6	.73	.83	3.94
19	Native,	3	800	12	6.9	7.7	36.3	4.7	5.4	4.9	.32	.40	1.80
20	Native,	9	850	6	18.1	19.7	94.1	4.2	4.5	4.4	.78	.89	4.17

Pounds of Food and Nutrients per Day per 1000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Val. (En gy.)	Protein.	Fat.	Carbohy- drates.	Nutritive Ratio.	Fuel Val. (En gy.)
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
Corn meal,	-	3.1	.26	.14	2.17	.05	—	.15	.13	1.92	—
Wheat bran,	-	1.7	.31	.09	.92	.11	—	.24	.07	.65	—
Gluten meal,	-	2.1	.25	.30	1.24	.12	—	.22	.26	1.17	—
Total concentrat-											
ed food, -	-	6.9	.82	.53	4.33	.28	12340	.61	.46	3.74	10100
Fodder,*	-	7.5	.52	.19	3.15	1.78	—	.28	.10	3.05	—
Hay,	-	14.2	1.02	.44	6.41	3.32	—	.55	.24	5.87	—
Total coarse food,											
Total food, -	-	28.6	2.36	1.16	13.89	5.38	45100	1.44	.80	12.66	9.3
Minimum per day.											
Concentrated food	-	7.0	.83	.54	4.38	.27	12450	—	—	—	—
Coarse food, -	-	18.3	1.29	.52	7.99	4.31	27450	—	—	—	—
Total, -	-	25.3	2.12	1.06	12.37	4.58	39900	—	—	—	—
Maximum per day.											
Concentrated food	-	7.2	.83	.54	4.46	.28	12600	—	—	—	—
Coarse food -	-	23.3	1.66	.69	10.35	5.50	35500	—	—	—	—
Total, -	-	30.5	2.49	1.23	14.81	5.78	48100	—	—	—	—

* Fodder consisted of equal parts of poor hay and stover.

TABLE 30.

*Summary of Total and Digestible Nutrients Fed per Day per 1000
Lbs., Live Weight, on Sixteen Dairy Farms
in Connecticut.*

Reference No.	CLASSES OF FOOD.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbo- hydrates.	Nutritive Ratio.	Fuel Value (Energy).
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
1	Concentrated food,	1.87	.64	4.00	.65	14800	1.58	.55	3.51	—	11790
	Coarse food, -	1.80	.70	9.61	6.17	35700	.93	.44	9.73	—	21660
	Total food, -	3.67	1.34	13.61	6.82	50500	2.51	.99	13.24	6.2	33450
2	Concentrated food,	2.51	.56	6.22	.70	19900	2.05	.49	5.58	—	16300
	Coarse food, -	1.49	.57	9.17	6.00	33400	.74	.36	9.61	—	20700
	Total food, -	4.00	1.13	15.39	6.70	53300	2.79	.85	15.19	6.1	37000
3	Concentrated food,	2.71	.96	5.11	.63	19700	2.39	.87	4.65	—	16770
	Coarse food, -	1.20	.54	10.10	5.64	33800	.62	.28	10.13	—	21180
	Total food, -	3.91	1.50	15.21	6.27	53500	3.01	1.15	14.78	5.7	37950
4	Concentrated food,	1.81	.55	6.27	.54	18300	1.47	.46	4.99	—	14000
	Coarse food, -	2.14	.86	11.94	7.06	43000	1.15	.47	11.67	—	25800
	Total food, -	3.95	1.41	18.21	7.60	61300	2.62	.93	16.66	7.0	39800
5	Concentrated food,	2.64	.88	3.39	.31	15500	2.20	.76	2.64	—	12200
	Coarse food, -	1.90	.73	12.43	7.31	43300	.96	.49	12.55	—	27200
	Total food, -	4.54	1.61	15.82	7.62	58800	3.16	1.25	15.19	5.7	39400
6	Concentrated food,	1.56	.54	4.19	.20	13400	1.23	.51	3.58	—	11100
	Coarse food, -	1.49	.67	11.04	6.90	38900	.80	.36	10.97	—	23400
	Total food, -	3.05	1.21	15.23	7.10	52300	2.03	.87	14.55	8.1	34500
7	Concentrated food,	1.97	.74	8.96	.51	24400	1.44	.65	7.70	—	19740
	Coarse food, -	1.86	.81	11.23	5.87	38700	1.00	.44	10.30	—	22860
	Total food, -	3.83	1.55	20.19	6.38	63100	2.44	1.09	18.00	8.4	42600
8	Concentrated food,	2.08	.64	6.47	1.23	20900	1.60	.50	5.35	—	15050
	Coarse food, -	2.98	.79	11.75	7.74	45100	1.56	.43	11.60	—	26300
	Total food, -	5.06	1.43	18.22	8.97	66000	3.16	.93	16.95	6.0	41350
9	Concentrated food,	1.62	.65	3.81	.22	13240	1.20	.58	3.14	—	10500
	Coarse food, -	1.68	.49	8.68	5.62	31760	.96	.25	8.91	—	19450
	Total food, -	3.30	1.14	12.49	5.84	45000	2.16	.83	12.05	6.4	29950

TABLE 30.—(Continued.)

Reference No.	CLASSES OF FOOD.	TOTAL NUTRIENTS AND ENERGY.					DIGESTED NUTRIENTS AND ENERGY.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value (Energy).	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value (Energy).
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.		Cal.
10	{ Concentrated food,	1.57	.55	4.62	.27	14300	1.09	.50	3.72	—	11100
	{ Coarse food, -	2.11	.67	9.16	5.47	34000	1.23	.34	9.32	—	21000
	{ Total food, -	3.68	1.22	13.78	5.74	48300	2.32	.84	13.04	6.4	32100
11	{ Concentrated food,	2.51	.78	5.20	.43	18400	1.91	.70	4.17	—	14250
	{ Coarse food, -	1.58	.57	8.98	6.35	33900	.85	.31	9.29	—	20200
	{ Total food, -	4.09	1.35	14.18	6.78	52300	2.76	1.01	13.46	5.7	34450
12	{ Concentrated food,	2.96	.66	6.40	1.03	22100	2.29	.56	4.84	—	15650
	{ Coarse food, -	1.40	.57	6.38	3.95	24200	.70	.38	6.57	—	15100
	{ Total food, -	4.36	1.23	12.78	4.98	46300	2.99	.94	11.41	4.5	30750
13	{ Concentrated food,	2.25	.72	6.13	.56	19600	1.67	.64	5.27	—	15600
	{ Coarse food, -	1.03	.42	5.97	3.38	21100	.53	.28	5.90	—	13150
	{ Total food, -	3.28	1.14	12.10	3.94	40700	2.20	.92	11.17	6.0	28750
14	{ Concentrated food,	2.23	.85	4.95	.38	17690	1.71	.64	3.79	—	12900
	{ Coarse food, -	1.77	.76	9.77	5.47	34810	.95	.41	9.30	—	20850
	{ Total food, -	4.00	1.61	14.72	5.85	52500	2.66	1.05	13.09	5.8	33750
15	{ Concentrated food,	.92	.46	5.82	.28	15000	.70	.37	4.79	—	11800
	{ Coarse food, -	1.21	.36	9.24	5.55	31300	.65	.19	9.20	—	19100
	{ Total food, -	2.13	.82	15.06	5.83	46300	1.35	.56	13.99	11.3	30900
16	{ Concentrated food,	.82	.53	4.33	.28	12340	.61	.46	3.74	—	10100
	{ Coarse food, -	1.54	.63	9.56	5.10	32760	.83	.34	8.92	—	19500
	{ Total food, -	2.36	1.16	13.89	5.38	45100	1.44	.80	12.66	9.3	29600
<i>Averages of the Above Sixteen Ratios.</i>											
	Concentrated food, -	-	-	-	-	-	1.58	.58	4.47	—	13700
	Coarse food, -	-	-	-	-	-	.90	.36	9.62	—	21100
	Total food, -	-	-	-	-	-	2.48	.94	14.09	6.5	34800

Table 30, on pages 91 and 92, gives a summary of the rations fed on sixteen dairy farms in Connecticut. In the first five columns are given the total nutrients and total potential energy (fuel value) in the materials fed. The three following columns

give the calculated weights of digestible protein, fats and carbohydrates. As explained on page 74, these weights are calculated from the total nutrients by the use of factors (digestion coefficients) obtained from digestion experiments. These factors are only approximate, and the weights of nutrients obtained by their use are also approximate.

In order that a ration may be complete, there must be enough digestible protein supplied in the food to build new tissues (bone, muscle, milk, etc.) and repair the wastes of the body, and sufficient digestible fat and carbohydrates to furnish heat and muscular energy. If the sum of the digestible carbohydrates and two and one-fourth times the digestible fat of a ration is divided by the amount of digestible protein in the ration, the quotient gives what is called the nutritive ratio. If the quantities of digestible fat and carbohydrates are large relative to the protein, this number will be large and the ration is called a "wide ration;" if the quantities of digestible fat and carbohydrates are relatively small, the quotient is a small number and the ration is a "narrow" one. A ration where the nutritive ratio is much more than 1 : 6 may be called a "wide ration;" if much less it may be called a "narrow ration." "Wide rations" are much more common among American feeders than are "narrow" ones. The column next to the last contains the nutritive ratio of the rations fed.

The last column contains the total energy (fuel value) of the digestible nutrients in the rations. These figures were obtained by calculation as explained on page 17 of the present Report.

DISCUSSION OF THE RESULTS OF THE TESTS.

The results brought out in such a study as the one here reported, are tentative rather than final. This investigation was not undertaken with the expectation of obtaining startling facts nor would we be warranted in drawing very definite conclusions from the tests. We do believe, however, that there is much of practical importance to be obtained along this line of inquiry, and that the results herewith presented merit the careful attention of dairy-men.

It is probably true that the animals of most of the herds examined were, so far as breed, milk and butter product are concerned, above the average of cows kept for dairy purposes in Connecticut. It is doubtless true that the feeding practiced by the owners of these herds is better than that which is generally

practiced throughout the State. These facts, taken together with the shortness of the periods of observation to which the herds were subjected, have been kept in mind in the following discussion of the results of the tests.

The two chief uses of food are to form the materials of the body and make up its wastes, and to yield energy in the form of heat to keep the body warm, and furnish muscular and other power for the work it has to do. In forming the tissues and fluids of the body, the food serves for building and repair. In yielding energy it serves as fuel. The different nutrients of food act in different ways in accomplishing this purpose. The principal tissue formers are the protein compounds. They build up and repair the nitrogenous materials, as the muscle and bone, and supply the albuminoids of blood, milk, and other fluids. The chief fuel ingredients of the food are the carbohydrates and fat. These are either consumed in the body or are stored as fat to be used as occasion demands. As the protein compounds are the flesh formers, and since the chief function of the fats and carbohydrates is to furnish heat and muscular strength which may be measured by their potential energy or fuel value, it is possible to form a very good idea of the nutrients furnished in different rations by comparing the quantities of digestible protein and amounts of potential energy which the digestible nutrients of rations furnish.

It will be seen from table 30 that the smallest weight of digestible protein fed per day per 1,000 pounds live weight, was 1.35 pounds, and the largest amount was 3.16 pounds. The potential energy or fuel value of the digestible nutrients fed per 1,000 pounds live weight, varied from a minimum of 28,750 calories to a maximum of 42,600 calories. There was also a correspondingly large range in the nutritive ratio of the rations fed. The narrowest ration had the ratio of 1 : 4.5, the widest, of 1 : 11.3.

A RATION FOR A MILCH COW.

Every little while we are in receipt of letters something like this: "I should like to know, in plain, simple language, what is the best way for profit, to feed a cow of 1000 pounds live weight." Unfortunately such a question can at present be answered only approximately.

A proper daily ration will supply in appropriate forms, the protein needed to form the nitrogenous materials of the body

and the energy required for heat and muscular work, and a proper feeding standard will call for sufficient digestible protein, fats, and carbohydrates per day to meet these needs. But just what these weights should be is a matter of considerable uncertainty. No hard and fast rules can be laid down. Individuality (differences of individual animals) prevents the strict application of the general principles which have been learned. Differences in breed, handling, classes of food, powers of digestion, and numerous other conditions known and unknown, tend to make the individual equation one of great importance.

Twenty-five or more years ago there were suggested by Prof. Wolff, an eminent German chemist, certain standard rations for different kinds of animals fed for different purposes. His standard ration for a milch cow calls for 24 pounds of organic matter which should contain 2.5 pounds of digestible protein, .4 pounds of digestible fat, and 12.5 pounds of digestible carbohydrates per day per 1,000 pounds live weight. The potential energy of these digestible nutrients would be about 29,600 calories. Later experience in Germany has inclined toward making the ration narrower and somewhat larger. On the other hand, feeding practice in this country has been quite different, and even our best feeders generally feed a wider ration than that called for by the German standard. Foods rich in fats, and in starch and other carbohydrates are so cheaply and easily obtained in this country that our practice has been to feed them more liberally than has been the case in Germany. Some three or four years ago the New York Station made inquiries by correspondence with some of the best dairymen of the State as to the kinds and amounts of food they were feeding milch cows. Somewhat later the Wisconsin Station made the same inquiry of dairymen of that State. Based upon the replies which were received from eight dairymen in New York and fifteen in Wisconsin, and one study made in Connecticut by the State Station, the Wisconsin Experiment Station* recommended a daily ration, which "may be considered a standard American ration for milch cows in full flow of milk, weighing about 1,000 pounds," of 25.6 pounds organic matter, containing 2.2 pounds digestible protein, .8 of a pound digestible fat, 13.3 pounds digestible carbohydrates. The fuel value of this ration is about 32,200 calories, and its nutritive ratio 1 : 6.9. It will be noticed that the Wisconsin Station recommends in

* F. W. Woll, Wisconsin Experiment Station Bulletin No. 33, October, 1892, page 20.

this standard ration, .3 of a pound less digestible protein than Wolff's standard ration calls for and that the total energy is 2,600 calories larger. While in Germany there is a tendency to the increased use of protein, this standard ration advocates less protein and more of the fuel ingredients of the food.

The German figures were suggested after a great many accurate studies of the feeding practices of the best German feeders, and after a large number of feeding experiments had been conducted by trained specialists. This so-called American standard is practically the average of the feeding practice of 24 dairymen in New York and Wisconsin, and furthermore, as ascertained from the more or less accurate estimates of the feeders themselves as to the amounts fed, etc. The materials fed were not analyzed, but their composition was assumed from the averages of other analyses.

The above is said not in any way to discredit the American work already accomplished, for just such preliminary work as this must be done before other and more accurate observations can be made. The facts are stated, however, to aid us in forming an estimate as to the value of the two standards. Our conditions differ materially from those of Germany, and it may be they are such as to make it better economy to use as wide a ration and with as small an amount of protein as that of the standard prepared by the Wisconsin Experiment Station. This, however, is not at present demonstrated.

The rations here reported upon represent the actual feeding practices of the dairymen whose herds were examined, so far as could be learned by weighing the foods actually fed from day to day, and by determining their composition as accurately as may be by means of chemical analysis. The factors used for calculating the quantities of digestible nutrients are the chief sources of uncertainty entering into this study, but this uncertainty is at present inevitable. The average of these sixteen rations might be suggested as a Connecticut or a New England standard ration for milch cows. But when we consider that there were such wide variations in feeding practice, and when we find such ranges in amounts of protein and in total energy as are pointed out in table 30, on pages 91 and 92, and in table 31, page 97, it would be very unwise to assume that the average of the rations which these sixteen men were feeding was the best possible ration, or anything like the best possible ration, for milch cows in America. Because

carbohydrates and fats are so abundant and so cheap in this country that we feed them liberally, does not imply, much less prove, that we are using them wisely.*

We have so few American data upon the effects of rations, that the teachings of the sixteen studies here reported upon this question are of some value.

In table 31 (page 99) are summarized the rations fed, together with the yield of butter-fat observed during the five days of the tests. The weight of butter-fat was selected rather than the weight of milk, as it is less liable to fluctuation from day to day, and also remains more constant during the earlier months of lactation. In this tabulation the butter yields of all the animals under two years of age, and which were more than eight months in milk flow, have been omitted. Also, in one or two instances, animals giving unusually small yields were also omitted from the tabulations. The animals were of different breeds, and in many ways the conditions were such that the results are not strictly comparable one with the other, and yet in the lack of better data the results are here tabulated to show what light they throw upon the question of the effects of protein and the nutritive ratio upon the production of butter-fat. In this summary table, the figures are made to conform more nearly to "round numbers." Thus the weights of digestible protein are given to the nearest .05 of a pound, 2.51 pounds being taken as 2.50, etc.

The average butter-fat yields for the five days are grouped in accordance with the size of the nutritive ratio of the rations and the weights of protein fed. The butter-yields from the

*After this article was in type and the preceding pages were printed, a Bulletin (Bulletin 38, Wisconsin Experiment Station, by F. W. Woll,) upon "One Hundred American Rations for Dairy Cows," was received. This Bulletin presents results of further observations upon dairy feeding similar to those described in Bulletin 33 of that Station. The rations fed were obtained in the same way as those of the earlier Bulletin. Letters were "sent to four hundred dairy farmers and breeders of dairy stock in all parts of the United States and Canada, asking information concerning their methods of feeding milch cows." * * * "One hundred of the farmers to whom the circulars were sent furnished complete rations containing definite quantities of the feeding stuffs fed daily to their cows, *as exactly as the circumstances would permit.*" [The italics are ours.]

"Combining all of the rations which have been fed by successful dairy farmers and breeders in various parts of our continent, we have the following American ration": Dry matter, 24.51 pounds, containing 2.15 pounds digestible protein, .74 pounds digestible fat and 13.27 pounds digestible carbohydrates. The nutritive ratio of this ration is 1 to 6.9, and the estimated fuel value of its digestible nutrients is 31,250 calories.

This ration differs from the one given in Bulletin 33 of the Wisconsin Station by containing 1.5 pounds less organic matter, .15 pounds less digestible protein, and its potential energy is 950 calories less. The amounts of digestible protein in these rations ranged from 1.05 pounds to 4.34 pounds, the fuel value of the digestible nutrients ranged from 19,050 calories to 45,600, and the nutritive ratios varied from 1 to 4.1, to 1 to 12.8.

herds which had a nutritive ratio greater than 1:6, are given in the fifth, and those which had a nutritive ratio less than 1:6 in the sixth columns. It will be observed that the average five days' yield per cow of the animals of the wider rations was 3.9, and that of the animals of the narrower was 4.5 pounds butter-fat in five days. The animals having the narrower ration produced on the average .6 of a pound more of butter-fat in five days than did those having the wider.

In the last two columns of the table, the butter-fat yields are averaged in accordance with the amount of digestible protein in the rations. It will be observed that the herds which received more than 2.3 pounds of digestible protein per day gave an average of 4.5 pounds per cow of butter-fat in five days, while those under 2.3 gave only 3.6 pounds per cow of butter-fat in the same time. In other words, the animals having the larger amounts of protein gave on the average .9 of a pound more of butter-fat in five days than did those having the smaller quantities of protein.

With the exception of the animals of herd 10, those which are classified as receiving more than 2.3 pounds of digestible protein were all actually receiving about 2.5 or more pounds of digestible protein per day. The animals of this herd (10) were all practically new milch, six of them having just calved, five of the others being less than two months after calving, and all but one being four months or less since calving. This would seem to account, in part at least, for the high yield of butter-fat.

The largest butter-fat yields, with the exception of that from herd 10, were from herds 12, 3, 14 and 1. The rations fed these herds contained respectively 2.99, 3.01, 2.66 and 2.51 pounds of digestible protein. Their nutritive ratios were as follows: 1:4.5, 1:5.7, 1:5.8, 1:6.2. Their fuel values were 30,750, 37,950, 33,750 and 33,450 calories. Too much importance should not be attached to these results, as they may have been partly accidental and due to causes other than feed. It is, nevertheless, a noteworthy fact that in the cases in which the cows were in about the same period of lactation, the yields of butter-fat decreased as the protein decreased, and as the nutritive ratio increased. The largest yield was from a herd receiving a very narrow ration (1:4.5) and one which contained a large amount (about 3 pounds) of digestible protein. The average of all these rations is a good deal wider than that of the German (Wolff's) standard, being very nearly as wide as that of the Wisconsin Station. The weight of

protein in the average of all the rations is in accord with Wolff's ration (2.5 pounds digestible protein), and the rations which seem to have given the best returns contained more protein than Wolff's standard calls for. From the fact that the best butter-fat yields were obtained from a ration containing less than 31,000 calories of potential energy, it seems fair to assume that those which contained upward of 40,000 were quite excessive.

TABLE 31.

Summary of rations fed and yields of butter-fat obtained from sixteen herds examined. The yields of butter-fat are classified in accordance with the nutritive ratios of the ration and the amounts of digestible protein which they contain.

SUMMARY OF RATIONS FED.					AVERAGE YIELDS OF BUTTER-FAT PER COW IN 5 DAYS.			
Reference No.	Total Organic Matter.	Digestible Protein.*	Nutritive Ratio.†	Fuel value of Digestible Nutrients.	Nutritive Ratio.		Digestible Protein.	
					Greater than 1:6	Less than 1:6	More than 2.3 Pounds.	Less than 2.2 Pounds.
	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs.	Lbs.
1, - -	25.4	2.50	6.0	33450	—	4.6	4.6	—
2, - -	27.2	2.80	6.0	37000	—	4.2	4.2	—
3, - -	26.9	3.00	5.5	37950	—	5.3	5.3	—
4, - -	31.2	2.60	7.0	39800	3.5	—	3.5	—
5, - -	29.6	3.15	5.5	39400	—	4.1	4.1	—
6, - -	26.6	2.05	8.0	34500	3.7	—	—	3.7
7, - -	32.0	2.45	8.5	42600	4.6	—	4.6	—
8, - -	33.7	3.15	6.0	41350	—	4.3	4.3	—
9, - -	22.8	2.15	6.5	29950	3.8	—	—	3.8
10, - -	24.4	2.30	6.5	32100	5.0‡	—	5.0	—
11, - -	26.4	2.75	5.5	34450	—	4.0	4.0	—
12, - -	23.4	3.00	4.5	30750	—	5.5	5.5	—
13, - -	20.5	2.20	6.0	28750	—	3.6	—	3.6
14, - -	26.2	2.65	6.0	33750	—	4.7	4.7	—
15, - -	23.8	1.35	11.5	30900	3.3	—	—	3.3
16, - -	22.8	1.45	9.5	29600	3.8	—	—	3.8
Average,	26.4	2.50	6.5	34800	3.9	4.5	4.5	3.6

*As here tabulated, the weights of protein are given to the nearest .05 of a pound; thus 2.51 lbs. are called 2.50, etc.

†As here tabulated, the nutritive ratios are taken to the nearest .5; thus 6.2 is called 6; 6.4 is called 6.5, etc.

‡Cows nearly all new milch. Nutritive ratio 1 : 6.4.

The evidence at present at our command would seem to indicate that the quantity of digestible protein called for by the German (Wolff's) standard is none too large, and that it would be safe in the general run of cases to feed as much or even more protein

if we would obtain the largest yields of butter-fat from our milch cows. It would also, perhaps, be wiser until we have more light than we have at present upon this matter, to make our rations larger, so far as their total energy is concerned, than that of the German standard. The size of the ration suggested by the Wisconsin Station as a standard ration may, when it is measured by its fuel value, not be too large for the demands of our conditions. Feeding stuffs rich in carbonaceous foods (fats and carbohydrates) are abundant and cheap with us, and it is difficult to utilize the foods ordinarily produced on the farm without making our rations larger in total energy than the German standard calls for.

The use of fuel values gives a means of simplifying the calculation of rations. It will be understood that the proportions of fats and carbohydrates are only relative, in other words, that one may be diminished if the other be correspondingly increased. If our theories are correct, the important matter is to provide sufficient protein and sufficient total energy without varying too much from the most desirable relative proportions of the fats and carbohydrates. In other words, a daily ration for a milch cow (1,000 pounds live weight) which would furnish 2.5 pounds of digestible protein and enough digestible carbohydrates and fats to make up the 29,600 calories of energy, would satisfy the requirements of the German (Wolff's) standard, although the relative proportions of the carbohydrates and fats were not the same as called for by this particular standard.

TABLE 32.

German (Wolff's) and Wisconsin Station Standard Rations, together with Averages of 16 Rations here reported upon, and a tentatively suggested Ration.

RATION.	ORGAN- IC MATTER	DIGESTIBLE NUTRIENTS.				Nutritive Ratio.
		Protein.	Fat.	Carbohy- drates.	Fuel Value.	
Wolff's (German)	1 lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Standard, - -	24.0	2.50	.40	12.50	29600	5.4
Wisconsin Station						
Standard, 1893, -	25.6	2.30	.80	13.30	32200	6.9
Wisconsin Station						
Standard, 1894, -	24.5	2.15	.74	13.27	31250	6.9
Average of 16 here						
reported, - -	26.4	2.48	.94	14.09	34800	6.5
Tentatively suggest-						
ed ration, - -	25.0	2.50	(.5 to .8*)	(13 to 12*)	31000*	5.6

* See explanation on the opposite page.

The German (Wolff's) standard ration, the standard ration proposed by the Wisconsin Experiment Station, the averages of the 16 rations here reported upon and a suggested tentative ration are given in table 32, on the opposite page.

As has been already pointed out, the chief function of the fats and carbohydrates is to serve as fuel. It appears to be more important that these nutrients should be provided in sufficient quantities for the needs of the body than that they should be supplied in definite relative proportions. In the tentative ration thus suggested, the energy called for could be furnished by about .5 of a pound of digestible fat and 13.0 pounds digestible carbohydrates; by .6 of a pound of digestible fat and 12.5 pounds of digestible carbohydrates; or by .8 of a pound of digestible fat and 12 pounds of digestible carbohydrates.

It must be borne in mind that a "standard ration" itself is only an estimate, an effort to express proportions which approximate the average needs of different animals or the quantities which may be fed. "A great deal of experimenting with the calorimeter and the respiration apparatus, and a great deal of practical testing of animals in experimental stables and on the farm, will be needed in order to enable us to make such estimates entirely satisfactory. When that research shall be accomplished, its results will have a very great value to the farmer."

DAILY VARIATIONS IN AMOUNTS FED.

While there may be more or less uncertainty as to what is a proper ration, there can be no question but what better results will be obtained from careful than from careless feeding. If the animals are overfed one day and underfed, or even properly fed, the next, the milk flow will be affected to the disadvantage of the dairymen. It is not always easy to carefully regulate the quantities of the coarse foods, hay and fodders, which are given from day to day. It is difficult to judge accurately of the weight since the compactness or looseness will deceive the eye. There is, however, very little if any, reason why the same, or nearly the same, weights of the concentrated feeds should not be given from day to day. It may not be practicable to weigh the feeds in the barn when they are being fed, but it is easy to measure the quantities of grain and avoid any great changes in amounts from day to day.

Table 33, which follows, shows the variations in size of the rations which were fed in these sixteen different herds.

TABLE 33.

Variations in Amounts of Food and Total Nutrients per 1000 Lbs., Live Weight, with the same Herd on Different Days, as Shown by the Weights of Food and Nutrients in the Day's Ration, with the Smallest (Minimum) and the Largest (Maximum) Total Energy.

Ref. No.		Con- centrated Food.	Coarse Food.	Total Food.	Protein.	Fat.	Nitrogen- free Extract.	Fiber.	Total Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
1	Minimum, -	4.9	42.7	47.6	2.82	1.02	11.42	6.26	42400
	Maximum, -	10.3	44.4	54.7	4.18	1.54	14.77	7.20	55300
	Average, -	8.3	43.6	51.9	3.67	1.34	13.61	6.82	50500
2	Minimum, -	10.6	57.4	68.0	3.36	.94	13.37	5.48	45300
	Maximum, -	11.8	66.2	78.0	4.84	1.28	16.65	7.83	57100
	Average, -	11.4	64.7	76.1	4.00	1.13	15.39	6.70	53300
3	Minimum, -	10.7	25.8	36.5	3.85	1.45	14.34	5.62	50400
	Maximum, -	10.7	30.2	40.9	3.98	1.54	16.26	6.99	57100
	Average, -	10.7	27.9	38.6	3.91	1.50	15.21	6.27	53500
4	Minimum, -	9.9	29.3	39.2	3.80	1.33	17.14	7.28	58100
	Maximum, -	11.2	34.0	45.2	4.16	1.48	19.80	8.39	66600
	Average, -	10.6	30.5	41.1	3.95	1.41	18.21	7.60	61300
5	Minimum, -	8.0	45.2	53.2	4.43	1.56	14.81	7.08	55500
	Maximum, -	8.1	53.7	61.8	4.75	1.69	17.54	8.51	64400
	Average, -	8.2	46.3	54.5	4.54	1.61	15.82	7.62	58300
6	Minimum, -	7.4	25.6	33.0	3.00	1.19	14.78	6.92	51000
	Maximum, -	7.5	29.2	36.7	3.00	1.20	16.27	7.69	55200
	Average, -	7.5	26.6	34.1	3.05	1.20	15.23	7.10	52300
7	Minimum, -	13.8	23.9	37.7	3.75	1.51	19.80	6.23	61800
	Maximum, -	13.8	25.0	38.8	3.89	1.57	20.47	6.51	64000
	Average, -	14.1	24.4	38.5	3.83	1.55	20.19	6.38	63100
8	Minimum, -	11.8	23.5	35.3	4.46	1.27	15.90	7.55	57300
	Maximum, -	12.7	34.6	47.3	5.75	1.61	20.90	10.62	76100
	Average, -	12.2	28.7	40.9	5.06	1.43	18.22	8.97	66000
9	Minimum, -	6.6	20.1	26.7	3.02	1.04	11.28	5.28	40800
	Maximum, -	7.7	23.4	31.1	3.45	1.18	13.17	6.20	47400
	Average, -	7.4	22.2	29.6	3.30	1.14	12.49	5.84	45000
10	Minimum, -	8.1	20.6	28.7	3.52	1.16	13.04	5.28	45400
	Maximum, -	8.0	26.4	34.4	4.04	1.33	15.37	6.69	54200
	Average, -	8.2	22.3	30.5	3.68	1.22	13.78	5.74	48300
11	Minimum, -	10.4	19.9	30.3	3.92	1.29	13.28	6.05	48700
	Maximum, -	10.2	23.8	34.0	4.28	1.39	14.54	7.24	54300
	Average, -	10.2	22.6	32.8	4.09	1.35	14.18	6.78	52300
12	Minimum, -	12.7	48.2	60.9	4.28	1.19	12.49	4.89	45300
	Maximum, -	13.3	50.3	63.6	4.54	1.30	13.76	5.47	49700
	Average, -	13.1	48.5	61.6	4.36	1.23	12.78	4.98	46300
13	Minimum, -	11.0	37.0	48.0	3.24	1.13	11.88	3.84	40000
	Maximum, -	11.1	40.1	51.2	3.31	1.15	12.30	4.04	41400
	Average, -	11.2	38.2	49.4	3.28	1.14	12.10	3.94	40700
14	Minimum, -	9.4	20.2	29.6	3.83	1.53	13.78	5.35	49200
	Maximum, -	9.7	22.9	32.6	4.12	1.66	15.11	5.99	53900
	Average, -	9.4	22.3	31.7	4.00	1.61	14.72	5.85	52500
15	Minimum, -	8.0	17.3	25.3	1.85	.72	13.19	5.00	40300
	Maximum, -	9.5	23.2	32.7	2.55	.94	17.16	6.52	52800
	Average, -	8.8	20.3	29.1	2.13	.82	15.06	5.83	46300
16	Minimum, -	7.0	18.3	25.3	2.12	1.06	12.37	4.58	39900
	Maximum, -	7.2	23.3	30.5	2.49	1.23	14.81	5.78	48100
	Average, -	6.9	21.7	28.6	2.36	1.16	13.89	5.38	45100

As pointed out on page 100, the size of a ration can be conveniently measured by its digestible protein and by the fuel value (potential energy) of its digestible nutrients. Since digestion factors are not so very different one from another, it follows that the weights of *total* protein and the *total* fuel values of different rations will serve the purpose of approximate comparisons. In table 33 the total nutrients, not the digestible nutrients, are given.

In general, there seems to have been, as was to be expected with the class of farmers that we visited, considerable care exercised to insure regularity in times of feeding and amounts fed. With the exception of herds 1, 2, 3 and 9, there were no larger variations in the amounts of grain fed from day to day than one would expect. In some cases, notably 3, 5, 6, 7, 10, 11, 13 and 16, the amounts of grain given from day to day were practically constant. In the case of these same herds there was for the most part a corresponding evenness in the daily milk flow and its content of butter-fat. This probably did not follow from the greater uniformity in feed any more than that of the care in general, as it would doubtless be true that the man who is most careful in his feed would be careful in other particulars regarding his herd. In general the quantities of feed given were more uniform where a mixture was made of the grains and then all fed from one measurement than was the case where each grain was fed from a separate bin. The chief objection to feeding the grain in a mixture is that it does not allow as good opportunity for varying the feeds of different animals, as is the case when the grains are fed separately. If a careful person is attending to the feeding, and is trying to feed each animal properly, and is carefully watching the effects of the feed, the best results would doubtless be obtained by feeding the different grain feeds from separate bins. If hired help has to be depended upon, a grain mixture would, in most cases, prove to be the most satisfactory method of feeding grain.

DISCUSSION OF RATIONS.

In the following pages there are given in tabular form the kinds and amounts of the different feeding stuffs actually fed in the 16 herds studied by the Station in the winter of 1893, together with the pounds of protein,* the fuel value of the digestible nutrients, the nutritive ratio and the cost of the ration.

* The terms protein, nutritive ratio, fuel value, etc., are explained on pages 93-100.

There are also given in the case of each ration two suggested changes. It is hoped that out of the forty-eight rations which are given herewith farmers will be enabled to find a ration which is suited to their own needs and circumstances, and that they may be more or less of a guide toward a better feeding. The suggested rations are given as examples of the way in which the same feeding stuffs may be combined in other, and in general, probably better rations. All that has been said in the preceding pages, calling attention to the fact *that there is no such thing at present known as a "best ration," and that all attempts to express in terms of protein and energy the needs of a dairy cow, are only approximations, must be kept in mind in the study of the following rations.*

The costs of the different rations have been calculated by use of the following prices for the different feeds. The prices of the different concentrated feeds are the average, as ascertained by Dr. Jenkins of the State Station, at which they were sold in Connecticut in December, 1893.

Wheat bran, - -	\$19 00	Oats, - - - -	\$21 00
Wheat middlings, -	21 00	Malt sprouts, - -	18 00
Cotton seed meal, -	26 00	Rye meal, - - -	21 00
Buffalo gluten feed, -	21 00	Oat feed, - - -	21 00
Chicago gluten meal, -	25 00	Hay, - - - -	18 00
Cream gluten meal, -	25 00	Ensilage, - - -	2 50
O. P. linseed meal, -	30 00	Oat hay, - - -	14 00
N. P. linseed meal, -	28 00	Poor hay, - - -	10 00
Corn meal, - -	21 00	Stover, - - -	8 00
Hominy meal, - -	20 00	Rowen, - - -	14 00
Corn and cob meal, -	20 00		

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 1, and Suggested Rations.*

RATION NO. 1.	AS FED.	SUGGESTED CHANGES.	
	A.	B.	C.
Wheat bran, - -	2.8 pounds.	4.0 pounds.	5.0 pounds.
Wheat middlings, -	1.6 pounds.	2.0 pounds.	—
Linseed meal, - -	1.8 pounds.	2.0 pounds.	2.0 pounds.
Buffalo gluten feed, -	2.1 pounds.	3.0 pounds.	5.0 pounds.
Hay, - - -	11.0 pounds.	4.0 pounds.	—
Oat hay, - - -	5.3 pounds.	8.0 pounds.	3.0 pounds.
Ensilage, - - -	27.3 pounds.	25.0 pounds.	50.0 pounds.
Digestible protein, -	2.50 pounds.	2.50 pounds.	2.50 pounds.
Fuel value, - -	33,450 calories.	31,550 calories.	31,350 calories.
Nutritive ratio, 1: -	6.2	5.8	5.7
Cost of ration, - -	26.3 cents.	23.3 cents.	23.3 cents.

Ration No. 1, as fed, was fairly well balanced. The fuel value was perhaps somewhat larger than necessary. Nearly all the cows of this herd were young, all except five being three years or under. It is likely that animals at this stage of growth, especially when in milk flow, would need more protein than mature animals would. The chief criticism to be made in this case is the same as can be made of the majority of rations fed upon New England farms. It contains too much of first quality hay. Taking the hay at its market value, such a ration is more expensive than one which uses more of the cheaper coarse feeds and less of good hay. Each of the suggested rations (B and C) contains less hay than the one actually fed. The coarse feed of ration C is almost wholly ensilage. Each of the suggested rations contains the same amounts of digestible protein as the ration which was actually fed. The fuel value is about 2,000 calories less in the suggested rations than in the one actually fed, and the nutritive ratio is smaller in consequence. Ration B costs three cents less, and ration C five cents less than A.

Daily Ration per 1000 Pounds Live Weight Actually Fed to Hera No. 2, and Suggested Rations.

RATION NO. 2.	AS FED.	SUGGESTED CHANGES.	
	A.	B.	C.
Wheat middlings, - -	4.7 pounds.	5.0 pounds.	6.0 pounds.
Chicago gluten meal, - -	3.7 pounds.	5.0 pounds.	4.0 pounds.
Provender, { Ground oats, -	1.0 pounds.	—	1.0 pounds.
{ Corn meal, -	2.0 pounds.	1.0 pounds.	2.0 pounds.
Good hay, - - - -	7.2 pounds.	—	7.0 pounds.
Poor hay, - - - -	2.2 pounds.	3.0 pounds.	—
Ensilage, - - - -	55.3 pounds.	50.0 pounds.	25.0 pounds.
Digestible protein, - -	2.80 pounds.	2.50 pounds.	2.50 pounds.
Fuel value, - - - -	37,000 calories.	31,450 calories.	30,650 calories.
Nutritive ratio, 1: - -	6.1	5.8	5.5
Cost of ration, - - -	2.72 cents.	20.3 cents.	22.3 cents.

Ration No. 2, as fed, was large in protein and fuel value, but was fairly balanced. If about one-ninth less of each of the ingredients had been used, it would have come very closely in its protein and fuel value to the tentatively suggested standard ration of page 100. A grain mixture of one part oats and two parts corn, such as used here (frequently called provender), seems to be quite a common grain feed in Connecticut. There are some reasons to doubt the economy of using oats as a feed

for milch cows. The suggested ration B does not contain oats. Chicago gluten meal contains a great deal of protein, and it would not be wise to change at once animals which had not been receiving gluten meal, to a ration containing as much gluten meal as ration B. All changes of feeds should be made gradually, so that the animal may become accustomed to the new ration without derangement. Ration C is heavier in grain than either B or A. It will be observed that both the rations B and C contain the weights of protein called for by the suggested standard, and that the fuel value of B is a little greater and that of C a little less than the standard calls for. Ration C is five cents and ration B seven cents cheaper than ration A. If ration A were reduced one-ninth, it would give a fairly well-balanced ration of about the proper size and its cost would be reduced to 24 cents. B and C would then be respectively two and four cents cheaper than A.

Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd No. 3, and Suggested Rations.

RATION NO. 3.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Cotton seed meal, - -	4.1	pounds.	3.0	pounds.
Buffalo gluten feed, - -	3.1	pounds.	3.0	pounds.
Hominy meal, - - -	3.5	pounds.	4.0	pounds.
Hay, - - - -	11.0	pounds.	5.0	pounds.
Stover, - - - -	9.3	pounds.	15.0	pounds.
Potatoes, - - - -	7.6	pounds.	—	—
Digestible protein, - -	3.00	pounds.	2.50	pounds.
Fuel value, - - - -	37,950	calories.	31,400	calories.
Nutritive ratio, 1:	5.7		5.6	
Cost of ration, - - -	25.7	cents.*	21.5	cents.

* Exclusive of the potatoes.

Ration No. 3, as fed, contained about three pounds of digestible protein, and nearly 38,000 calories of energy. The ration was about one-sixth larger than called for by the tentatively suggested standard. The ration contained a very large amount (4.1 pounds) of cotton seed meal. Buffalo gluten feed is not as rich in protein as is either Chicago gluten meal or cream gluten. Still the cotton seed meal and the Buffalo gluten, taken together furnish two-thirds of the protein which would be called for by the standard. Hominy meal differs but little from corn meal in its composition. It contains about the same percentage of protein as corn meal, and more of fat and less of

carbohydrates, so that the fuel values of the two are about the same (1,400 calories per pound). The ration, as fed, contained nearly eight pounds per day of potatoes. Potatoes are not very valuable as a feed for the actual nutrients which they contain. They are popularly supposed to have some physiological action aiding digestion, etc., which is not shown by their chemical composition. It may be that as large weights of cotton seed and gluten as were here used can be safely fed, but so heavy a ration as this would demand careful attention of the feeder to avoid milk fever and other diseases incidental to high feeding. The suggested rations (B and C) are much smaller than A, though their nutritive ratios are about the same. If one-sixth less of each of the ingredients of ration A were fed, the ration would be much like B and C in total protein and fuel value. The use of less hay and more stover in rations B and C make them cost less than ration B, even after reducing the size of A one-sixth.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 4, and Suggested Rations.*

RATION No. 4.	AS FED.	SUGGESTED CHANGES.		
	A.	B.	C.	
Wheat bran, - - -	3.7 pounds.	6.0 pounds.	5.0 pounds.	
Cotton seed meal, - -	1.5 pounds.	3.0 pounds.	3.0 pounds.	
Corn and cob meal, - -	5.4 pounds.	—	5.0 pounds.	
Hay, - - - -	21.4 pounds.	3.0 pounds.	5.0 pounds.	
Stover, - - - -	9.1 pounds.	20.0 pounds.	15.0 pounds.	
Digestible protein, - -	2.60 pounds.	2.50 pounds.	2.50 pounds.	
Fuel value, - - -	39,800 calories.	31,300 calories.	31,300 calories.	
Nutritive ratio, 1:	7.0	5.6	5.6	
Cost of ration, - - -	33.8 cents.	20.3 cents.	23.7 cents.	

Ration No. 4, as fed, contains a little more protein than called for by the tentatively suggested ration, and its fuel value (nearly 40,000 calories) is far in excess. The nutritive ratio is wider than it is probably profitable to feed. This ration contained over 21 pounds of hay, which made it expensive, costing about 34 cents per 1,000 pounds live weight per day. Each of the suggested rations B and C contains much less hay than A, and the grain is used in such quantities as to make the total ration contain about $2\frac{1}{2}$ pounds of protein and 31,000 calories of potential energy. The cost of these suggested rations is much less than that of A. It would not be wise to make a sudden change from such a ration as A to either B or C or other narrow ration.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 5, and Suggested Rations.*

RATION No. 5.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Wheat middlings, - -	2.2	pounds.	6.0	pounds.
Chicago gluten meal, - -	2.7	pounds.	3.0	pounds.
Cotton seed meal, - -	3.3	pounds.	1.0	pounds.
Hay, - - - -	13.3	pounds.	6.0	pounds.
Ensilage, - - - -	33.0	pounds.	50.0	pounds.
Digestible protein, - -	3.15	pounds.	2.50	pounds.
Fuel value, - - -	39,400	calories.	30,500	calories.
Nutritive ratio, 1:	5.7		5.5	
Cost of ration, - - -	28.1	cents.	23.0	cents.

All of the grain feeds of ration No. 5 are quite rich in protein. The ration itself is a very large one, though very well balanced. The ration as actually fed furnished 3.15 pounds of digestible protein, and its fuel value was over 39,000 calories. If one-fifth less of each of the ingredients of the ration had been fed, it would have been of about the same size as the suggested rations B and C, and its cost would have been about the same as B, and considerably less than C. Ration C is an illustration of the fact that hay, if used in considerable amount, makes an expensive ration. Ration B contains two pounds more of grain than ration C, but costs nearly four cents less. This difference is chiefly due to the smaller amounts of hay and larger amounts of ensilage used in B than in C.

*Daily Ration per 1,000 Pounds Live Weight Actually Fed to Herd
No. 6, and Suggested Rations.*

RATION No. 6.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Corn meal, - - -	3.7	pounds.	2.0	pounds.
Wheat middlings, - -	2.0	pounds.	5.0	pounds.
Cotton seed meal, - -	1.8	pounds.	3.0	pounds.
Oat hay, - - - -	4.7	pounds.	5.0	pounds.
Hay, - - - -	14.4	pounds.	—	—
Stover, - - - -	7.5	pounds.	14.0	pounds.
Digestible protein, - -	2.05	pounds.	2.50	pounds.
Fuel value, - - -	34,500	calories.	31,000	calories.
Nutritive ratio, 1:	8.1		5.6	
Cost of ration, - - -	27.5	cents.	20.4	cents.

Ration No. 6 is low in protein and high in potential energy. The nutritive ratio (8.1) is greater than that of any of the rations which have preceded it. It will be observed that half the grain was corn meal, a feed relatively rich in the carbonaceous ingredients (fats and carbohydrates) and deficient in protein. Oat hay contains rather more protein than ordinary hay does. Hence the daily use of five pounds of oat hay made this ration better than it otherwise would have been. In each of the suggested rations (B and C) good hay was omitted. The digestible protein, the fuel values and nutritive ratio and cost of rations B and C are practically the same. A change from such a ration as A to B or C, or other narrow rations, should be made gradually. These suggested rations would probably be better if part of the cotton seed meal were replaced by gluten or linseed meal.

Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd No. 7, and Suggested Rations.

RATION NO. 7.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Provender, } Ground oats, -	2.8	pounds.	—	2.0 pounds.
} Corn meal, -	5.7	pounds.	3.0 pounds.	4.0 pounds.
Wheat middlings, -	5.6	pounds.	4.0 pounds.	6.0 pounds.
O. P. linseed meal, -	—		4.0 pounds.	3.0 pounds.
Hay, - - -	24.4	pounds.	19.0 pounds.	11.0 pounds.
Digestible protein, -	2.45	pounds.	2.50 pounds.	2.50 pounds.
Fuel value, - - -	42,600	calories.	30,000 calories.	31,000 calories.
Nutritive ratio, 1:	8.4		5.6	5.6
Cost of ration, - -	36.7	cents.	30.5 cents.	26.4 cents.

Ration No. 7, as fed, consisted of hay, middlings and provender (oats and corn ground together). This ration contained about enough digestible protein, but the total fuel value was very large. The feeding of 24 pounds of hay made the ration an expensive one. In ration B, in order to get sufficient protein, linseed meal has been suggested in pretty large amount. It is safer to feed four pounds of linseed than the same amount of cotton seed, as the cotton seed would contain one-third more protein. While the total protein of B is not greatly different from that of A, the nutritive ratio is so very different that any changes should be made gradually. In both rations B and C, good hay is the only coarse food. If stover or oat hay were substituted for part of the hay of B and C, the rations would be much more economical ones.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 8, and Suggested Rations.*

RATION NO. 8.	AS FED.	SUGGESTED CHANGES.	
	A.	B.	C.
Wheat bran, - - -	4.9 pounds.	5.0 pounds.	5.0 pounds.
Corn and cob meal, - -	7.3 pounds.	4.0 pounds.	7.0 pounds.
Malt sprouts, - - -	—	6.0 pounds.	4.0 pounds.
Hay, - - - - -	28.7 pounds.	15.0 pounds.	12.0 pounds.
Digestible protein, - -	3.15 pounds.	2.50 pounds.	2.50 pounds.
Fuel value, - - -	41,350 calories.	31,500 calories.	30,850 calories.
Nutritive ratio, 1:	6.0	5.7	5.6
Cost of ration, - - -	38.0 cents.	27.6 cents.	26.2 cents.

Ration No. 8, as fed, was very large, containing 3.15 pounds of digestible protein, and its fuel value was over 41,000 calories. The ration was fairly well balanced, but was altogether too large. If about one-fifth less had been fed, the food would probably have been utilized to better advantage. The use of so much hay made the ration an expensive one. In the suggested rations malt sprouts have been added to the grain feed used. In B, six pounds of malt sprouts replace three pounds of corn and cob meal and 14 pounds of A; and in ration C, four pounds of malt sprouts are fed with 17 pounds less hay than in ration A. Reducing the quantities of hay and increasing the grain feeds reduced the cost of the ration very materially. If, however, some of this hay could be replaced by some cheaper form of coarse foods, the price of the ration would be still farther reduced.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 9, and Suggested Rations.*

RATION NO. 9.	AS FED.	SUGGESTED CHANGES.	
	A.	B.	C.
Corn meal, - - - -	2.0 pounds.	4.0 pounds.	2.0 pounds.
Wheat bran, - - -	1.5 pounds.	2.0 pounds.	1.0 pounds.
Cotton seed meal, - -	1.5 pounds.	1.0 pounds.	1.0 pounds.
Cream gluten, - - -	1.5 pounds.	1.0 pounds.	1.0 pounds.
Hay, - - - - -	12.0 pounds.	—	—
Rowen, - - - - -	5.1 pounds.	12.0 pounds.	15.0 pounds.
Stover, - - - - -	5.1 pounds.	10.0 pounds.	10.0 pounds.
Digestible protein, - -	2.15 pounds.	2.50 pounds.	2.50 pounds.
Fuel value, - - -	29,950 calories.	31,500 calories.	30,600 calories.
Nutritive ratio, 1:	6.4	5.7	5.6
Cost of ration, - - -	23.8 cents.	24.0 cents.	20.1 cents.

Ration No. 9 is quite small, as estimated by its fuel value, and it is also deficient in protein. Its nutritive ratio is quite large (6.4). The use of more rowen and stover in ration B, with more corn meal and about the same quantities of bran and other nitrogenous feeds as in A, gives a larger and better balanced ration for the same cost. The use of larger quantities of rowen in C, with a corresponding decrease in the quantity of grains fed, gives a well balanced ration of about the proper size for 20 cents. The value of rowen and of clover in particular as a feed is pointed out in both these rations and in ration No. 10, where by using 15 or 16 pounds of rowen with stover and a comparatively small quantity of grain, a complete ration is furnished for 20 cents per 1000 pounds live weight.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 10, and Suggested Rations.*

RATION NO. 10.	AS FED.	SUGGESTED CHANGES.	
	A.	B.	C.
Corn meal, - - - -	4.6 pounds.	2.0 pounds.	2.0 pounds.
Cotton seed meal, - - -	2.3 pounds.	1.5 pounds.	2.5 pounds.
Wheat bran, - - - -	1.3 pounds.	2.0 pounds.	3.0 pounds.
Stover, - - - -	6.9 pounds.	8.0 pounds.	8.0 pounds.
Rowen, - - - -	10.2 pounds.	16.0 pounds.	7.0 pounds.
Hay, - - - -	5.2 pounds.	—	8.0 pounds.
Digestible protein, - - -	2.30 pounds.	2.50 pounds.	2.50 pounds.
Fuel value, - - - -	32,100 calories.	30,800 calories.	30,900 calories.
Nutritive ratio, 1: - - -	6.4	5.6	5.6
Cost of ration, - - - -	23.3 cents.	20.3 cents.	23.5 cents.

Ration No. 10, as fed, differs from 9 only in being a little larger. Practically the same suggested changes are made for this ration as for No. 9, only as gluten meal was not used in No. 10, the quantities of cotton seed and wheat bran are correspondingly increased. Ration B of No. 10 and ration C of No. 9 are among the least expensive of the suggested rations.

Ration No. 11 (see next page), as fed, was a well balanced ration, but was larger than probably needed. The two suggested rations, B and C, are alike so far as their digestible protein, fuel value and nutritive ratio are concerned. The grain mixtures and coarse foods of the two are, however, quite different. Ration B, which uses oat hay instead of merchantable hay, is four cents cheaper than C.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 11, and Suggested Rations.*

RATION NO. 11.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Wheat middlings, - - -	3.1	pounds.	2.0	pounds.
Corn meal, - - -	3.1	pounds.	—	6.0
Cotton seed meal, - - -	3.1	pounds.	3.0	pounds.
Wheat bran, - - -	0.8	pounds.	3.0	pounds.
Hay, - - -	12.1	pounds.	—	10.0
Oat hay, - - -	6.7	pounds.	12.0	pounds.
Stover, - - -	3.8	pounds.	10.0	pounds.
Digestible protein, - - -	2.75	pounds.	2.50	pounds.
Fuel value, - - -	34,450	calories.	31,500	calories.
Nutritive ratio, 1:	5.7		5.7	
Cost of ration, - - -	28.2	cents.	21.2	cents.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 12, and Suggested Rations.*

RATION NO. 12.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Wheat bran, - - -	3.8	pounds.	2.0	pounds.
Corn meal, - - -	2.3	pounds.	4.0	pounds.
Cotton seed meal, - - -	2.4	pounds.	1.0	pounds.
Malt sprouts, - - -	4.6	pounds.	6.0	pounds.
Ensilage, - - -	41.1	pounds.	50.0	pounds.
Hay, - - -	7.4	pounds.	3.0	pounds.
Digestible protein, - - -	3.00	pounds.	2.50	pounds.
Fuel value, - - -	30,750	calories.	31,100	calories.
Nutritive ratio, 1:	4.5		5.6	
Cost of ration, - - -	24.7	cents.	21.8	cents.

Ration No. 12 is the narrowest of the 16. It contains three pounds of digestible protein, and the fuel value of the ration is not quite 31,000 calories. Its nutritive ratio is 1 to 4.5. The animals upon this ration gave the best returns, so far as the five days' tests show, of any of the herds examined, and so far as it is allowable to make deductions from one such test, the use of larger quantities of protein than suggested in the tentative standard ration of page 100, would seem to be justified. The suggested rations B and C are wider and contain less protein than A. Their fuel values are about the same as that of A, and their costs are a little less. If malt sprouts could be bought at the price (\$12.50 per ton) at which they were used in this ration in 1893, the ration would be a very cheap one.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 13, and Suggested Rations.*

RATION NO. 13.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Cotton seed meal, - -	1.6	pounds.	2.5	pounds.
Wheat middlings, - -	6.4	pounds.	6.0	pounds.
Corn meal, - - - -	3.2	pounds.	4.0	pounds.
Ensilage, - - - -	30.7	pounds.	40.0	pounds.
Hay, - - - -	7.5	pounds.	5.0	pounds.
Digestible protein, - -	2.20	pounds.	2.45	pounds.
Fuel value, - - - -	28,750	calories.	31,300	calories.
Nutritive ratio, 1:	6.0		5.8	5.6
Cost of ration, - - -	22.8	cents.	23.3	cents.

Ration No. 13 was a small one in both its digestible protein and its fuel value. Ration B differs from A principally in containing a pound more of cotton seed meal and some less hay. It contains a little less digestible protein and its nutritive ratio is a little wider than that suggested on page 100. Ration C contains less wheat middlings and ensilage and more corn meal and hay than either A or B. It is a well balanced ration of about the proper size. Each of the rations B and C is a little more expensive than A.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 14, and Suggested Rations.*

RATION NO. 14.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Cream gluten, - - - -	3.1	pounds.	3.5	pounds.
Oat feed, - - - -	3.1	pounds.	2.0	pounds.
Wheat bran, - - - -	3.1	pounds.	5.0	pounds.
Hay, - - - -	18.7	pounds.	—	7.0
Stover, - - - -	3.6	pounds.	20.0	pounds.
Digestible protein, - -	2.65	pounds.	2.50	pounds.
Fuel value, - - - -	33,750	calories.	31,600	calories.
Nutritive ratio, 1:	5.8		5.7	5.7
Cost of ration, - - -	26.6	cents.	19.2	cents.

Ration No. 14, as fed, is a little larger than the standard calls for, but is fairly well balanced. The use of quite large quantities of hay makes the ration somewhat expensive. Ration B is a well balanced ration of the standard size, costing only 19 cents. This low cost is due to the use of stover alone for coarse food. If some other material than oat feed were used, the ration

could be made a little cheaper. C differs from B chiefly in having more hay and less stover. It is a considerably more expensive ration than B.

Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd No. 15, and Suggested Rations.

RATION NO. 15.	AS FED.		SUGGESTED CHANGES.	
	A.		B.	C.
Corn and cob meal, - -	5.8	pounds.	2.0	pounds.
Rye meal, - - - -	1.0	pounds.	—	2.0
Wheat bran, - - - -	0.9	pounds.	3.0	pounds.
Oat feed, - - - -	0.6	pounds.	3.0	pounds.
O. P. linseed meal, - -	0.6	pounds.	3.0	pounds.
Gluten meal bran, - -	—	—	1.0	pounds.
Malt sprouts, - - - -	—	—	—	4.0
Hay, - - - - -	11.8	pounds.	6.0	pounds.
Stover, - - - - -	8.5	pounds.	12.0	pounds.
Digestible protein, - -	1.35	pounds.	2.50	pounds.
Fuel value, - - - -	30,900	calories.	30,800	calories.
Nutritive ratio, 1:	11.3		5.6	5.7
Cost of ration, - - -	23.0	cents.	23.2	cents.

Ration No. 15 is the widest, that is, contains the least digestible protein in proportion to its other nutrients, of any of the rations examined. It has only 1.35 pounds of digestible protein, with a nutritive ratio of 1 to 11.3. It is not practicable to make a well balanced ration out of the materials which were fed in this case; hence the grains fed in B and C differ in kind from those of A. It is to be observed that both B and C are well balanced rations furnishing $2\frac{1}{2}$ pounds of digestible protein, and have practically the same fuel values and costs as A. This instance illustrates the fact that it costs no more to feed a well balanced than an illy balanced ration. There can be little doubt but that either B or C would give a great deal better returns than were obtained from A.

Ration No. 16 (see next page) is also very wide. It contains only 1.45 pounds of digestible protein and less than 30,000 calories of energy. The addition of more grain, including linseed meal, makes a ration which is well balanced and at no more cost, as is shown by rations B and C. It will be observed that while B and C contain about the same quantities of digestible protein and differ little in their fuel values, that the rations are quite different in their make-up.

*Daily Ration per 1000 Pounds Live Weight Actually Fed to Herd
No. 16, and Suggested Rations.*

RATION No. 16.	AS FED.	SUGGESTED CHANGES.		
	A.	B.	C.	
Corn meal, - - -	3.1 pounds.	2.0 pounds.	1.0 pounds.	
Wheat bran, - - -	1.7 pounds.	6.0 pounds.	3.0 pounds.	
Buffalo gluten feed, - - -	2.1 pounds.	4.0 pounds.	5.0 pounds.	
O. P. linseed meal, - - -	—	2.0 pounds.	2.5 pounds.	
Hay, - - -	14.2 pounds.	—	6.0 pounds.	
Poor hay, - - -	3.8 pounds.	6.0 pounds.	3.0 pounds.	
Stover, - - -	3.8 pounds.	7.0 pounds.	8.0 pounds.	
Digestible protein, - - -	1.45 pounds.	2.50 pounds.	2.50 pounds.	
Fuel value, - - -	29,600 calories.	31,000 calories.	31,000 calories.	
Nutritive ratio, 1: - - -	9.3	5.6	5.6	
Cost of ration, - - -	23.9 cents.	22.0 cents.	23.6 cents.	

As stated at the commencement of this paper, the studies here reported upon were undertaken as the beginning of an investigation into the feeding practices and the characters of the dairy herds of Connecticut. The investigation is being continued during the present winter, and it is expected that full accounts of the later results will be printed in the Annual Report of this Station for 1894.

It is our belief that the results thus far obtained merit the careful consideration of dairy farmers. The subject of cattle feeding and handling is a large one, and only general principles can be advanced. No hard and fast rules for feeding are now known, and doubtless none ever will be known. It is nevertheless true that the man who exercises the largest amount of good judgment, based upon all that the most advanced science can bring to him, and who tries to put into practice the knowledge thus acquired, will be on the much surer road to success than one who works blindly. There may be no "best" breed, no "best" ration, and no "best" way of handling dairy stock, yet there are bad sides to all three questions, and the man who learns to avoid the bad is well on the road toward the best.

METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.



The meteorological observations made at the Storrs Station during 1893 have been similar to those of past years. The Station equipment consists of the ordinary instruments for obtaining temperature, pressure of the air, humidity, rainfall and snowfall, uniform with those used by voluntary observers for the U. S. Weather Service. In addition to the records made at Storrs, the rainfall for the growing season has been recorded by farmers conducting field experiments for the Station, and a few other voluntary observers.

The rainfall for the year, as measured at the Station (46.7 in.), is a little below the average of the State. The average for six Connecticut stations of the New England Meteorological Society, having records covering a period of ten or more years prior to 1890, is 49.1 inches. The records at Storrs for the five years ending with 1893, give an average of 46.8 inches.

The precipitation was largest during May and smallest during the months of June, July, and the first half of August. It will be noticed that the rainfall was deficient during just that portion of the year when most needed by the greater part of our common farm crops. These conditions caused great injury to such crops as corn, potatoes, grass and tobacco.

The temperature for the first two months of the year was considerably below the average, and the snowfall was quite heavy during the latter part of the winter.

The spring opened a little later than usual. The last damaging frost occurred May 8th. The summer months were characterized by frequent drying winds and a moderate temperature, with light rainfall till after the middle of August.

Light frost appeared on low ground Sept. 3d. The first killing frost occurred Oct. 17th. This gave a growing season of 161 days since the last damaging frost in the spring, while the average growing season, since the Station began its observations in 1888, is 145 days.

During October the rainfall was large, and the supply of water in wells and springs was generally replenished.

Through the kindness of the New England Meteorological Society we are able to publish rainfall records from fourteen of their Stations.

Table 34 gives the rainfall as recorded for the six months ending October 31st, for twenty-two localities in the State, and table 35 gives the summary of observations made by the Station at Storrs.

TABLE 34.
Rainfall during Six Months ending Oct. 31, 1893.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village, - -	M. H. Dean, - -	5.52	2.49	3.33	5.50	3.89	3.99	24.72
Oxford, - - -	H. R. Stevens, -	7.63	2.64	2.80	7.81	2.51	5.31	28.70
Norwalk, - - -	G. C. Comstock,*	6.84	2.10	3.64	6.57	2.38	5.16	26.69
Waterbury, - -	N. J. Welton,*	6.44	1.82	3.31	7.22	1.75	5.21	25.75
New Hartford, -	R. R. Smith,*	7.16	2.09	2.51	5.47	3.23	6.48	26.94
Canton, - - -	G. J. Case,*	7.52	5.00	1.95	4.91	3.23	5.92	28.53
West Simsbury,	S. T. Stockwell,*	6.75	3.52	2.37	4.29	2.83	5.01	24.77
Hartford, - - -	Prof. S. Hart,*	7.44	2.06	1.64	4.14	2.36	4.72	22.36
Wallingford, - -	Mrs. B. F. Harrison,*	8.06	2.35	2.24	4.75	—	4.87	—
New Haven, - -	Weather Bureau,*	7.08	2.07	1.89	4.86	2.24	4.75	22.89
Middletown, - -	C. W. Hubbard,*	7.20	2.99	—	4.98	2.55	5.54	—
South Manchester,	K. B. Loomis, -	5.03	3.01	3.42	4.58	2.61	4.62	23.27
Vernon, - - -	E. H. Lathrop, -	5.59	2.98	2.63	4.15	2.06	—	—
Storrs, - - -	Experiment Station,	7.12	1.98	1.58	3.79	2.38	6.71	23.56
North Franklin,	C. H. Lathrop, -	8.34	3.73	2.25	3.43	2.75	4.91	25.41
Lebanon, - - -	J. H. Tucker, -	8.19	2.17	1.17	3.64	3.56	5.56	24.29
Lebanon, - - -	Edward Hoxie, -	8.63	3.81	1.11	3.53	3.42	4.42	24.92
Colchester, - -	S. P. Willard,*	7.97	1.90	1.43	4.23	3.06	6.60	25.19
New London, - -	Weather Bureau,*	5.02	3.60	1.51	3.69	2.29	2.20	18.31
Lake Konomoc, -	N. London W.Wks.*	7.17	2.63	0.91	3.37	2.72	—	—
Voluntown, - -	Rev. E. Dewhurst,*	7.10	2.57	1.48	4.14	2.22	3.83	21.34
N. Grosvenordale, -	C. H. Truesdell,*	6.03	1.75	1.27	4.03	2.44	4.55	20.07
Average, - - -		6.99	2.65	2.12	4.69	2.69	5.02	24.32

* New England Meteorological Society Observers.

TABLE 35.
Meteorological Summary for 1893.
 OBSERVATIONS MADE AT STORRS BY THE STATION.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Means.	Totals.
Highest barometer, -	30.50	30.79	30.52	30.61	30.29	30.32	30.19	30.24	30.37	30.59	30.68	30.90	30.50	—
Lowest barometer, -	29.17	29.04	29.34	29.44	29.23	29.68	29.61	29.49	29.66	29.38	29.63	29.42	29.42	—
Mean barometer, -	29.97	30.10	30.05	30.07	29.88	30.02	29.94	29.97	30.02	30.10	30.10	30.10	30.03	—
Highest temperature, -	50.5	48.5	48.8	68.4	84.8	91.1	88.8	89.5	77.2	74.8	62.0	55.7	70.0	—
Lowest temperature, -	-6.0	-3.0	6.0	20.0	35.5	45.0	47.8	46.0	37.0	25.0	14.0	-2.0	22.1	—
Mean temperature, -	17.3	23.5	30.3	42.0	54.5	64.2	67.9	68.0	55.9	51.7	38.1	27.8	45.1	—
Relative humidity, -	—	—	—	76.3	74.9	79.2	71.7	77.0	79.5	78.9	—	—	76.8	—
Total precipitation, -	2.39	5.88	4.67	3.82	7.12	1.98	1.58	3.79	2.58	6.71	2.45	3.68	—	46.65
Number of days with precipita- tion of .01 inches or more, }	9	13	13	11	13	9	8	11	9	6	6	13	—	121
Number of clear days, -	9	8	13	9	10	10	17	15	14	11	8	6	—	130
Number of fair days, -	12	9	8	9	11	12	10	9	6	13	13	16	—	128
Number of cloudy days, -	10	11	10	12	10	8	4	7	10	7	9	9	—	107

FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The Station has continued its coöperative field experiments through a sixth year, the plan being essentially the same as that adopted in the spring of 1888.

The field experiments conducted by the Station at Storrs and on farms in different parts of the State for the year 1893, have been largely "Soil Tests." One "Special Nitrogen" experiment on Hungarian grass was made at the Station.

Owing to the severe drought during July and August the crops on nearly all of the fields experimented upon were considerably injured, and the effects of the fertilizers were much less than might otherwise have resulted. On many of the fields the texture and the amount of organic matter of the soil of different plots varied considerably, and hence the available moisture supply was not the same on all. This, in most of the experiments, influenced the plot yields unequally and makes deductions from the use of the fertilizers more or less unreliable. For this reason there are given, for several of the experiments, simply tabulations of the results without deductions or comment. In other words, most of the experiments are made of little value by the drought, nevertheless it seems wise to put the results on record.

The object aimed at is to study the soils of different regions, learn their deficiencies, and find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical way. The wide variations in soils indicate that the results of any one experiment are applicable only to the particular soil experimented upon, or to soils of a similar character. Where this class of experimenting is wholly on the Station farm, the work has only a local value, and in order to make the experiments of highest value to the farmers of the State they must be carried out in a considerable number of places. If the important operations, such as the selection of the field, the laying out of the plots, the planting, the application of the fertilizers, and the weighing and harvesting of the crop, are under the supervision of an officer of the

Station, there is no reason why the work cannot be carried out with the same degree of accuracy on farms about the State as at the Station.

A summary of the results of fifteen years' experimenting by soil tests with fertilizers on farms throughout New England will be found in the last annual report of this Station.* The reader is referred to this for a more extended report on the value of such experiments and the practical deductions.

The following persons have coöperated in the experiments during the past year:

						POST OFFICE.
M. H. Dean,	-	-	-	-	-	Falls Village.
Elbert Manchester,	-	-	-	-	-	Bristol.
M. H. & H. G. Sperry,	-	-	-	-	-	Bolton.
William E. Alvord,	-	-	-	-	-	Bolton.
C. H. Lathrop,	-	-	-	-	-	North Franklin.
C. A. Sharpe,	-	-	-	-	-	Abington.

In connection with most of the experiments, rainfall records have been kept during the growing season. On page 117 will be found the rainfall records for the six months ending October 31st, for 22 localities in the State.

TABLE 36.

Percentages of Dry Matter of Corn in Ears (Grain and Cob), and the Number of Pounds of Ears required for a Bushel of Shelled Corn.

NAME AND LOCALITY.	Water-free Corn in sample (ears) at Harvest.		Pounds of ears at harvest to equal 56 lbs. shelled corn with 11 % water.	
	Good.	Poor.	Good.	Poor.
	%	%	Lbs.	Lbs.
M. H. Dean, Lime Rock, - - -	57.5	52.5	83	97
William E. Alvord, Bolton, - -	57.3	55.5	87	98
M. H. & H. G. Sperry, Bolton, - -	55.7	51.0	89	97
Elbert Manchester, Bristol, - -	54.2	40.0	92	125
C. A. Sharpe, Abington, - - -	60.9	53.0	82	94
C. H. Lathrop, North Franklin, -	56.2	50.7	88	98

* See Fifth Annual Report, 1892, pages 67-84.

POUNDS REQUIRED FOR A BUSHEL OF DRY SHELLED CORN.

The percentages of water at harvest in the corn of the different experiments are found to vary considerably. The field weights are not an accurate measure of the value of the crop. The moisture and the proportions of cob to corn vary widely on different fields, but have been found to be fairly uniform on different plots of the same field. Moisture tests of the corn, at the time of harvest, have been made for all but one of the experiments in order to find the number of pounds of ears required to make a bushel of dry shelled corn. The differences in the percentages of water-free corn may be ascribed to two causes; variations in the proportion of corn to cob and variations in the moisture contained in the ears at harvest. Owing to heavy rainfalls this year, while the corn was in the shocks, it was not as well dried as usual at harvest. Mr. Manchester grew a dent variety, and the corn seemed quite moist at harvest. The corn in nearly all cases contained a larger percentage of water than usual, and there are quite wide variations in the different experiments.

These differences point out the importance of knowing the moisture in the crop of each field instead of depending upon averages. From 70 to 75 pounds are commonly considered a sufficient weight of ears to make one bushel of dry shelled corn, but in these experiments an average of 88 pounds was required.

SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consists in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station in standard commercial forms, such as nitrate of soda, dissolved bone-black, and muriate of potash. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus \$2 per ton for mixing and freights.

On the following pages, the comparative yields of the experiments discussed are shown by means of diagrams. The fertilizers and the weights are given at the left of the diagram. The lengths of the lines represent the comparative yields per acre from the different plots, and the figures given in the last column show the actual yields per acre.

At the close of this article will be found a series of tabular statements, giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

EXPERIMENTS BY M. H. DEAN.

The field upon which these experiments were located is in the Housatonic Valley. The soil is alluvial, light loam, with very little vegetable matter, and apparently worn down by previous cropping without manure.

Experiments similar to the one of 1893 were conducted by the Station on this field in 1889 and 1890, the order of plots and the kinds of fertilizers being the same each year. The quantities of fertilizers used in 1890 were double those used in 1889, for each plot. The most marked results of the earlier experiments were the large increase in yield from the use of potash and nitrogen, and the apparently injurious effects of phosphoric acid. In both the years 1889 and 1890 plot E, with nitrate of soda and muriate of potash, gave a larger yield than plot G with the same fertilizers and dissolved bone-black in addition. In 1890, plot *Ga* was added in place of the plaster plot (H). This plot was similar to G in the amount of nitrogen and potash used, but had a very large amount of phosphoric acid. The yield on *Ga* was somewhat greater than on G, but was less than on E, where only potash and nitrogen were used.

This led to the query as to whether the soluble phosphoric acid, in the form of dissolved bone-black, did not prove injurious to the crop. The following was offered, at that time, as a possible means of explaining the peculiar phenomenon:

"This apparently injurious effect of soluble phosphates is most frequent on sandy soils, naturally deficient in nitrogen. The most plausible explanation seems to be that the soluble phosphoric acid, in the absence of an abundant supply of available nitrogen, checks the growth and hastens maturity. The leaves turn yellow and the crop prematurely ripens, and a smaller yield results."

In 1891 an experiment in green manuring was undertaken on this field for the purpose of ascertaining if the absence of an available supply of nitrogen might account for the lighter yields of corn when soluble phosphates were present in excess.

Cow peas were sown broadcast upon the entire field about June 1st, 1891, at the rate of one bushel per acre. A medium heavy growth was produced, and the crop was plowed under and

the field seeded to rye the first week in September. The weight of unthreshed rye per acre at harvest is given in the following table:

WEIGHTS OF UNTHRESHED RYE PER ACRE.

LBS. PER ACRE.		LBS. PER ACRE.		LBS. PER ACRE.	
Plot O, -	3130	Plot D, -	4180	Plot F, -	4470
Plot A, -	3740	Plot oo, -	4060	Plot G, -	4610
Plot B, -	3840	Plot E, -	4600	Plot Ga, -	4470
Plot C, -	4400				

From this tabulation it will be noticed that the plots to which potash had been applied in the corn experiments (see diagram on next page) gave the largest yields of rye, although the phosphoric acid plot (B) gave better results than nitrogen plot (A).

From the diagram on the next page giving the yields of corn for the three years 1889, 1890, and 1893, it will be seen that naturally the soil was especially lacking in potash and nitrogen; and that the clover plowed under added largely to the supply of available nitrogen. In 1893, mineral fertilizers alone (plot F) gave nearly as large yields as plot G, which had in addition to the minerals, 160 pounds of nitrate of soda.

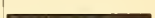
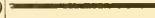
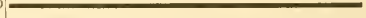
Early in the spring of 1892, red clover seed, at the rate of ten pounds per acre, was sown broadcast upon the entire field, and a fair "catch" resulted. The clover developed quite rapidly after the rye was harvested, and a heavy growth was produced during the fall of 1892. The clover was plowed under May 20 and 22, 1893, and the land prepared for a soil test experiment with corn. The kinds and amounts of fertilizers used were the same as for our regular soil tests (see weights for 1889), except plot Ga took the place of plaster. This plot had the same amount of nitrogen and potash as G, but double the amount of phosphoric acid.

A striking peculiarity of the soils of this region is the presence of large quantities of phosphates. The soil is alluvial, and was apparently formed from the decomposition of limestone formations located along the Housatonic Valley to the northward. This limestone evidently contains phosphates, and by its decomposition these phosphates must have been added to the soil. In the earlier experiments the dissolved bone-black (phosphoric acid) seemed to be detrimental to the crop, but in the latter test (1893), in the presence of an abundance of available nitrogen, it proved of value, although the increase in yield was slight where double the ordinary quantity was used (Plot Ga).

SOIL TEST WITH FERTILIZERS ON CORN.

By M. H. DEAN, LIME ROCK.

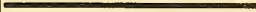
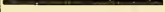
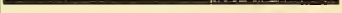
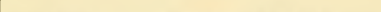
Fertilizers and Yields for 1889, 1890 and 1893.

Plot No.	FERTILIZERS.			YIELD SHELLED CORN PER ACRE IN 1889, 1890, 1893. (11 % Water.)	
	Kind.	Lbs. per Acre	Lbs. per Acre.	Comparative Scale.	Bu.
		<i>1889 and 1893.</i>	<i>1890.</i>		
O.	Nothing, -	—	—	{ 1889  1890  1893 	9.9 3.9 10.3
A.	Nit. of Soda, -	160	320	{ 1889  1890  1893 	16.9 12.9 16.2
B.	Dis. Bone-black,	320	640	{ 1889  1890  1893 	9.1 5.0 8.9
C.	Mur. of Potash,	160	320	{ 1889  1890  1893 	18.8 7.2 28.5
D.	{ Nit. of Soda, - Dis. Bone-black,	{ 160 320 }	{ 320 640 }	{ 1889  1890  1893 	18.0 17.0 22.0
OO.	Nothing, -	—	—	{ 1889  1890  1893 	14.7 7.3 19.3
E.	{ Nit. of Soda, - Mur. of Potash,	{ 160 160 }	{ 320 320 }	{ 1889  1890  1893 	25.3 44.4 32.6
F.	{ Dis. Bone-black, Mur. of Potash,	{ 320 160 }	{ 640 320 }	{ 1889  1890  1893 	17.4 8.8 36.9
G.	{ Nit. of Soda, - Dis. Bone-black, Mur. of Potash,	{ 160 320 160 }	{ 320 640 320 }	{ 1889  1890  1893 	22.1 35.0 39.5
H.	Plaster, - -	400	—	1889 	14.8
Ga.	{ Nit. of Soda, - Dis. Bone-black, Mur. of Potash,	{ — — — }	{ 320 1280 320 }	{ 1890  1893 	40.4 42.8

* H of 1889 is the same plot as Ga of 1890 and 1893.

SOIL TEST WITH FERTILIZERS ON CORN, 1893.

By M. H. DEAN, LIME ROCK.

Plot No.	FERTILIZERS.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o.	Nothing, - -	—		10.3
A.	Nitrate of Soda, -	160		16.2
B.	Dis. Bone-black, -	320		8.9
C.	Muriate of Potash, -	160		28.5
D.	{ Nitrate of Soda, - Dis. Bone-black, -	{ 160 320 }		22.0
oo.	Nothing, - -	—		19.3
E.	{ Nitrate of Soda, - Muriate of Potash, -	{ 160 160 }		32.6
F.	{ Dis. Bone-black, - Muriate of Potash, -	{ 320 160 }		36.9
G.	{ Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	{ 160 320 160 }		39.5
Ga.	{ Nitrate of Soda, - Dis. Bone-black, - Muriate of Potash, -	{ 160 640 160 }		42.8

Four points are especially emphasized in the experiment of 1893:

(1) The necessity of preparing fertilizers so as to meet the needs of soils.

(2) The importance of stocking light, porous soils with a large amount of organic nitrogen in order to supply nitrogen to the crop and get the best results from the mineral fertilizers.

(3) The value and economy of legumes for improving light, porous soils, by plowing in as manure.

(4) The evidence that soluble phosphates may prove a detriment to the crop on certain light soils, unless there is an abundance of available nitrogen present in the soil. In the absence of available nitrogen the phosphates seem to hasten maturity and thus shorten the life of the plant. This is a probable explanation of the way the phosphoric acid diminishes the yield.

SOIL TEST EXPERIMENT BY THE STATION ON COW PEAS.

This experiment is the fourth in a series of tests planned as a rotation soil test experiment, the same fertilizers being used on the same plots year after year.* Beginning with 1890 the crops grown on this field have been corn, potatoes, oats and cow peas. The plan was to grow scarlet clover in 1893, but the crop failed to make a good growth while young, and hence the test with clover was abandoned.

The field slopes gently to the south, but not enough to cause serious washing. The soil is a heavy loam, and the subsoil is a yellow, compact, clay loam. In 1889 it was noticed that the soil seemed to be poorer toward the west side of the field. For this reason the field was laid out into two half-acre experiments, the order of the plots on the two being reversed, as per diagram.

ARRANGEMENT OF PLOTS IN STATION EXPERIMENT.

UNMANURED STRIPS SEPARATE THE PLOTS.

For fertilizers used on plots, see diagram on opposite page.

EAST.			
NORTH.	PLOT O.	PLOT Y.	SOUTH.
	PLOT A.	PLOT X.	
	PLOT B.	PLOT OOO.	
	PLOT C.	PLOT G.	
	PLOT OO.	PLOT F.	
	PLOT D.	PLOT E.	
	PLOT E.	PLOT D.	
	PLOT F.	PLOT OO.	
	PLOT G.	PLOT C.	
	PLOT OOO.	PLOT B.	
PLOT X.	PLOT A.		
PLOT Y.	PLOT O.		
WEST.			

The yields of the duplicate plots in each case are averaged in estimating the yield per acre. This helps toward eliminating the errors due to irregularities of soil. All of the plots were laid out running north and south.

* For description and results of earlier experiments on this field, see Report of this Station, 1890, pp. 69-71.

Beside the regular soil test, two other plots were added, one (Y) with a medium amount of stable manure and the other (X) with a smaller quantity of manure, but in addition dissolved bone-black at the rate of 160 pounds per acre.

SOIL TEST WITH FERTILIZERS ON COW PEAS.

BY THE STATION, STORRS.

Plot No.	FERTILIZERS.		YIELD PER ACRE. (Vines 83 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Lbs.
o.	Nothing, - -	—		10,230
A.	Nitrate of Soda, -	160		10,960
B.	Dis. Bone-black,	320		10,710
C.	Muriate of Potash,	160		11,680
oo.	Nothing, - -	—		9,725
D.	{ Nitrate of Soda, - Dis. Bone-black,	{ 160 320 }		12,920
E.	{ Nitrate of Soda, - Muriate of Potash,	{ 160 160 }		13,335
F.	{ Dis. Bone-black, - Muriate of Potash,	{ 320 160 }		15,790
G.	{ Nitrate of Soda, - Dis. Bone-black, Muriate of Potash,	{ 160 320 160 }		16,210
ooo	Nothing, - -	—		12,100
X.	{ Stable Manure, - Dis. Bone-black,	{ 12,000 160 }		15,795
Y.	Stable Manure, -	16,000		15,875

Twenty pounds per acre of scarlet clover seed were sown April 25th, and the fertilizer was applied May 9th. Very heavy rain-falls, which occurred early in May, packed the surface soil and so retarded the growth of the clover that the weeds soon gained control. Early in June it was decided that the field should be planted to cow peas. The land was thoroughly harrowed June 5th and 6th, and all weeds destroyed. The field was thinly stocked with clover about two inches high at this time. The Clay variety of cow peas was sown June 7th, in drills 2 feet 4 inches apart, at the rate of 40 quarts per acre. The seed germinated well, and by June 17th the field was well stocked. No

marked differences were noticed in the growth on different plots till the latter part of July.

July 31st it was observed that the plots to which dissolved bone-black had been applied were making better growth than the other plots. This was noticeable on plots B, D and F. Later in the season the plots with potash took the lead.

As is usually the case with legumes, potash seemed to have the most marked influence on the yields. Plot C gave the heaviest growth of any of the plots with single fertilizers, while E with nitrogen and potash gave a considerably better growth than D with nitrogen and phosphoric acid.

The increase from the use of nitrogen (nitrate of soda or manure) was not very marked, as may be seen by comparing the yields on F with only mineral fertilizers with that on G with a complete fertilizer, and on Y with manure and X with manure and dissolved bone-black.

The percentage composition and the yield of the different nutrients per acre are shown in table 37, on the opposite page.

The influence of nitrogen on the composition of the crop of this experiment is quite interesting. Unlike the grasses, the legumes seem to be but little affected in their protein or nitrogen content by the addition of nitrogen in the fertilizers. Potash appeared to have the most marked influence over the percentage of protein in the crop. Plot C with potash alone, and Plot F with potash and phosphoric acid, gave the highest percentages of protein in the crop.

Plot G with a complete fertilizer costing \$12 per acre, yielded only 420 pounds per acre more than plot F, which had the same mineral fertilizers, but no nitrogen, and cost \$8 per acre. The total protein on the two plots was very different from the total crop. Plot G, with nitrate of soda, yielded protein at the rate of 496 pounds, while F, without the nitrate, produced at the rate of 534 pounds per acre.

This experiment points out two reasons for not using nitrogen compounds to any considerable degree, in the fertilizers used in growing leguminous crops. The total yield is but little if any greater where nitrogen is used, and the protein in the crop does not seem to be increased by its use.

TABLE 37.

*Proximate Composition of Water-free Substance of Cow Peas and
Proximate Ingredients per Acre in Cow Peas.*

Plot No.	FERTILIZERS.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
	<i>Composition.*</i>		%	%	%	%	%	%
o.	Unmanured, - -	1234	17.11	3.76	47.50	19.95	11.68	2.44
oo.	Unmanured, - -	1235	19.21	3.69	44.03	20.06	13.01	2.76
ooo.	Unmanured, - -	1236	18.83	3.07	44.17	21.02	12.91	2.70
	Av. of Unmanured,	—	18.38	3.51	45.24	20.34	12.53	2.63
A.	Nitrate of Soda, -	1237	17.02	3.44	48.59	19.86	11.09	2.45
B.	Dis. Bone-black, -	1238	18.94	3.28	45.23	20.22	12.33	2.70
C.	Muriate of Potash, -	1239	19.76	3.50	42.77	20.31	13.66	2.83
D.	{ Nitrate of Soda, - } { Dis. Bone-black, - }	1240	17.24	3.62	47.21	19.91	12.02	2.46
E.	{ Nitrate of Soda, - } { Muriate of Potash, - }	1241	16.01	3.48	45.06	22.60	12.85	2.34
F.	{ Dis. Bone-black, - } { Muriate of Potash, - }	1242	19.88	3.61	41.06	22.53	12.92	2.92
G.	{ Nitrate of Soda, - } { Dis. Bone-black, - }	1243	18.02	3.58	42.65	22.24	13.51	2.65
X.	{ Muriate of Potash, - } { Stable Manure, - }	1244	19.17	3.55	43.80	21.40	12.08	2.80
Y.	{ Dis. Bone-black, - } { Stable Manure, - }	1245	18.08	3.73	44.49	21.42	12.28	2.63
	FERTILIZERS.	<i>Dry Matter.</i> Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
o.	Unmanured, - -	1739	297	65	827	347	203	—
oo.	Unmanured, - -	1653	317	61	728	332	215	—
ooo.	Unmanured, - -	2057	387	64	909	432	265	—
	Av. of Unmanured,	—	334	63	821	370	228	—
A.	Nitrate of Soda, -	1863	317	64	905	370	207	—
B.	Dis. Bone-black, -	1821	345	59	824	369	224	—
C.	Muriate of Potash, -	1986	393	69	849	404	271	—
D.	{ Nitrate of Soda, - } { Dis. Bone-black, - }	2196	378	79	1037	438	264	—
E.	{ Nitrate of Soda, - } { Muriate of Potash, - }	2267	363	78	1021	513	292	—
F.	{ Dis. Bone-black, - } { Muriate of Potash, - }	2684	534	96	1101	605	348	—
G.	{ Nitrate of Soda, - } { Dis. Bone-black, - }	2755	496	98	1174	614	373	—
X.	{ Muriate of Potash, - } { Stable Manure, - }	2685	515	95	1176	575	324	—
Y.	{ Dis. Bone-black, - } { Stable Manure, - }	2699	487	100	1202	578	332	—

* For composition on fresh basis, see page 21 of this Report.

SPECIAL NITROGEN EXPERIMENT BY THE STATION ON HUNGARIAN GRASS.

The field used for the special nitrogen experiment on Hungarian grass is the same as was used during the past three years for similar experiments on mixed meadow grasses.*

DETAILS OF THE EXPERIMENT.

The experiment was similar to the special nitrogen experiments with corn, described in previous Annual Reports of the Station.† It will be observed that plots 1 to 5, on which nitrogen, phosphoric acid, and potash are applied singly and two by two, and also plot 6 with mixed minerals, were omitted from these experiments. These soil test plots were omitted for lack of room in the field, and not because interesting results might not have been expected from them.

The general plan of the experiment was to apply the same quantities of mineral fertilizers (potash and phosphoric acid) to all the plots except two, which were left unmanured. Nitrogen was added to all of the fertilized plots, except two, at the rate of 25, 50 and 75 pounds per acre. The whole experiment, as planned, includes the use of nitrogen in the three forms: nitrates, ammonia salts, and organic nitrogen. In the experiment with meadow grasses (1890-91-92), the three plots of the organic nitrogen group were omitted from the results, as there was much clover with the grasses. No fertilizers were applied on this part of the field during 1891 and 1892, and the amount of clover in the crop of 1892 was considerably reduced.

The field has a gentle slope to the south and southwest, but not enough to occasion the washing of fertilizers from one plot to another. The plots contained one-eighth acre each, and were laid out so as to conform to the slope of the field. They are 302.5 feet long by 18 feet wide, with unfertilized strips 3 feet wide between plots.

The soil is a medium heavy loam, and the sub-soil is slightly clayey and adhesive. The soil was in a comparatively low state

* Reports of this Station, 1890, pp. 44-56; 1891, pp. 29-40; 1892, pp. 36-46.

† See Reports of this Station, 1888, pages 72 to 89; 1889, pages 103 to 119; 1890, pages 71 to 74.

of fertility. The land is not quickly affected by drought, and appears to retain fertilizers readily. The natural drainage is good.

A crop of mixed meadow grasses was grown on the field in 1893 before the Hungarian experiment was started. This was cut and harvested June 8th-11th, and the field was plowed a few days later preparatory to the experiment. The crop of hay consisted mostly of fine grasses, except there was in addition some clover on plots 6*b*, 13, 14 and 15. The yield was about one ton per acre.

Owing to the severe drought at this period, it was thought advisable not to sow the seed at once. Hence the soil was simply kept free of weeds by harrowing several times, till July 8th, at which time the experiment was started.

NOTES DURING GROWTH.

The field was sown with Hungarian grass July 8th, at the rate of one bushel per acre. The fertilizer was applied after sowing the seed, and the land was then rolled. Light rains July 9th and 12th caused the seed to germinate fairly well. July 31st the field was found to be fairly well stocked, and the Hungarian was two to three inches high. At this date very little difference could be observed in the growth on the different plots.

August 8th the crop was 7 to 10 inches high on all of the fertilized plots, and appeared heavier and darker colored on the plots having had the larger quantities of nitrogen. The growth on the nothing plots was small, thin and pale-colored, and on the mixed mineral plots was slender and pale-colored. The growth on plots 8 and 9 was somewhat uneven.

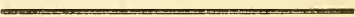
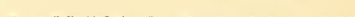
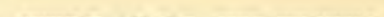
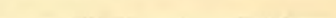
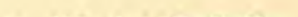
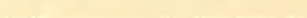
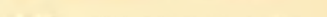
August 28th the crop was nearly grown and beginning to blossom. The growth on the fertilized plots seemed to be about twice as heavy as on the mixed mineral plots. The growth seemed heavier and darker green where the most nitrogen was used. The heaviest growth appeared to be on the sulphate of ammonia plots. The crop on the nothing plots was small, pale and thin, while that on the mineral plots was pale in color, but somewhat heavier than on the nothing plots. Plot 6*b* showed a much heavier growth than 6*a*.

The crop on the strips between the plots was cut and removed August 31st-Sept. 2d. The crop on the plots was cut Sept. 4th. At this time it was noticed that the growth on plots 8 and 9 was quite uneven, and that plot 6*b* showed a heavier crop than 6*a*. The Hungarian was a little past full bloom when cut.

RESULTS OF THE EXPERIMENTS.

In the diagram which follows, the comparative yields per acre are shown. The field weights for each plot are calculated to a uniform water basis of 11 per cent. moisture (89 per cent. dry matter).

Yield of Hay per Acre.

Plot No.	FERTILIZERS.		YIELD PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Lbs.
o.	Nothing, - -	—		3034
7.	{ Mixed Min's, as 6a,	480 }		3754
	{ Nitrate of Soda, -	160 }		
8.	{ Mixed Min's, as 6a,	480 }		3853
	{ Nitrate of Soda, -	320 }		
9.	{ Mixed Min's, as 6a,	480 }		3863
	{ Nitrate of Soda, -	480 }		
6a.	{ Dis. Bone-black, *	320 }		2624
	{ Muriate of Potash, *	160 }		
10.	{ Mixed Min's, as 6a,	480 }		3638
	{ Sulp. of Ammonia,	120 }		
11.	{ Mixed Min's, as 6a,	480 }		3857
	{ Sulp. of Ammonia,	240 }		
12.	{ Mixed Min's, as 6a,	480 }		4130
	{ Sulp. of Ammonia,	360 }		
6b.	Mixed Min's, as 6a,	480		3580
oo.	Nothing, - -	—		2321
13.	{ Mixed Min's, as 6a,	480 }		3133
	{ Ammonite, - -	192 }		
14.	{ Mixed Min's, as 6a,	480 }		3248
	{ Ammonite, - -	384 }		
15.	{ Mixed Min's, as 6a,	480 }		3414
	{ Ammonite, - -	576 }		

* Mixed Minerals.

The yields obtained in previous years on the plots (o and oo) having no manure and those having minerals alone (6a and 6b) would seem to indicate that the soil is tolerably uniform. The yield of the present year on these plots is very irregular. Plot o is on a steeper incline than the others, and it was thought that on this account it might have lost more than the others by washing, but this season the yield was much larger than that from plot 6a, which was supplied with mineral fertilizers. The yield from the mixed mineral plots also greatly lacked in uniformity. This may be due to the fact that there was considerable clover in the hay crop of one of these plots (6b) which was harvested in June, and the clover stubble and roots may have increased the available nitrogen on this plot over that on the other mixed mineral plot, 6a.

There was a gradual increase in yield with the increased quantities of nitrogen used. The crop in general did not show a very marked increase from the use of fertilizers. This was doubtless due in part to the severe drought during July and the greater part of August. The experiment confirms those made on the field with meadow grasses, in demonstrating the importance of nitrogenous fertilizers in the growth of grasses.

TABLE 38.

Proximate Composition of Water-free Substance of Hungarian.

Plot No.	FERTILIZERS.	Laboratory No.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Nitrogen.
			%	%	%	%	%	%
o.	Unmanured, - - -	1249	8.09	3.41	53.00	29.32	6.18	1.20
oo.	Unmanured, - - -	1250	9.82	3.22	50.65	29.74	6.57	1.47
	Average of Unmanured, -	—	8.96	3.31	51.83	29.53	6.37	1.34
6a.	{ Dis. Bone-black, { Mixed } { Mur. of Potash, { Min'ls, }	1251	8.48	2.96	50.79	30.40	7.37	1.24
	Mixed Minerals, as No. 6a,	1252	9.26	2.98	49.73	30.14	7.89	1.35
6b.	Av. of Mixed Minerals, -	—	8.87	2.97	50.26	30.27	7.63	1.30
	<i>Nitrate of Soda Group.</i>							
7.	{ Mixed Minerals, as No. 6a, } { Nit. of Soda (25 lbs. N.), }	1253	8.07	2.73	51.40	30.95	6.85	1.19
8.	{ Mixed Minerals, as No. 6a, } { Nit. of Soda (50 lbs. N.), }	1254	10.16	3.35	49.01	30.31	7.17	1.50
9.	{ Mixed Minerals, as No. 6a, } { Nit. of Soda (75 lbs. N.), }	1255	14.21	3.71	44.78	29.60	7.70	2.12
	<i>Sulphate of Ammonia Group.</i>							
10.	{ Mixed Minerals, as No. 6a, } { Sulph. of Am. (25 lbs. N.), }	1256	8.48	3.21	50.20	30.40	7.71	1.27
11.	{ Mixed Minerals, as No. 6a, } { Sulph. of Am. (50 lbs. N.), }	1257	8.66	2.76	49.12	31.64	7.82	1.30
12.	{ Mixed Minerals, as No. 6a, } { Sulph. of Am. (75 lbs. N.), }	1258	10.92	3.13	46.29	31.71	7.95	1.64
	<i>Organic Nitrogen Group.</i>							
13.	{ Mixed Minerals, as No. 6a, } { Ammonite (25 lbs. N.), }	1259	10.65	3.26	46.77	31.61	7.71	1.58
14.	{ Mixed Minerals, as No. 6a, } { Ammonite (50 lbs. N.), }	1260	11.90	3.40	45.93	31.14	7.63	1.78
15.	{ Mixed Minerals, as No. 6a, } { Ammonite (75 lbs. N.), }	1261	13.04	3.41	45.88	29.80	7.87	1.96

COMPOSITION OF THE CROP.

Samples of from 15 to 19 pounds were taken from each plot just before the hay was carted. These were cut into one-half inch lengths and sub-samples (of 3 to 5 lbs.) were taken for analysis.

From table 38 it will be seen that the nitrogen supplied in the fertilizers had considerable influence on the percentage of protein. The average percentage of protein in the water-free substance of the crop on the mineral plots was 8.87 per cent., on the plots with 25 lbs. of nitrogen 10.24 per cent., and with 75 lbs. of nitrogen, 12.72 per cent. This illustrates the double value of nitrogen on the grasses. The yield is generally increased with the larger quantities of nitrogen used, and the protein, and hence the feeding value of the crop is considerably increased.

TABLE 39.
Proximate Ingredients per Acre in Hungarian.

Plot No.	FERTILIZERS.	Laboratory No.	Water-free.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
o.	Unmanured, - - -	1249	2731	221	93	1447	801	169
oo.	Unmanured, - - -	1250	2089	205	67	1059	621	137
	Av. of Unmanured, - -	—	2410	213	80	1253	711	153
6a.	{ Dis. Bone-black, { Mixed Mur. of Potash, { Minerals, }	1251	2362	200	70	1200	718	174
6b.	Mixed Minerals, as No. 6a, -	1252	3132	290	93	1558	944	247
	Av. of Mixed Minerals, -	—	2747	245	82	1379	831	210
	<i>Nitrate of Soda Group.</i>							
7.	{ Mixed Minerals, as No. 6a, } { Nitrate of Soda (25 lbs. N.), }	1253	3379	273	92	1737	1046	231
8.	{ Mixed Minerals, as No. 6a, } { Nitrate of Soda (50 lbs. N.), }	1254	3468	352	116	1700	1051	249
9.	{ Mixed Minerals, as No. 6a, } { Nitrate of Soda (75 lbs. N.), }	1255	3477	494	129	1557	1029	268
	<i>Sulphate of Ammonia Group.</i>							
10.	{ Mixed Minerals, as No. 6a, } { Sulph. of Am. (25 lbs. N.), }	1256	3274	277	105	1644	996	252
11.	{ Mixed Minerals, as No. 6a, } { Sulph. of Am. (50 lbs. N.), }	1257	3471	300	96	1706	1098	271
12.	{ Mixed Minerals, as No. 6a, } { Sulph. of Am. (75 lbs. N.), }	1258	3717	406	117	1720	1179	295
	<i>Organic Nitrogen Group.</i>							
13.	{ Mixed Minerals, as No. 6a, } { Ammonite (25 lbs. N.), }	1259	2820	301	92	1319	891	217
14.	{ Mixed Minerals, as No. 6a, } { Ammonite (50 lbs. N.), }	1260	2923	348	99	1343	910	223
15.	{ Mixed Minerals, as No. 6a, } { Ammonite (75 lbs. N.), }	1261	3073	401	105	1409	916	242

TABLE 40.

SPECIAL NITROGEN EXPERIMENT ON HUNGARIAN.

Weight and Cost of Fertilizers per Acre, Total Crop and Increase of Crop over that of the Nothing Plots.

Plot No.	FERTILIZERS.	Weight of Fertilizers.	Cost of Fertilizers.	Total Crop (11 % Water).	Gain or Loss (-) Over Nothing Plots.
		Lbs.	\$	Lbs.	Lbs.
0.	Nothing, - - - - -	—	—	3034	—
7.	{ Mixed Minerals, as No. 6a, - - -	480 }	12.00	3754	1076
	{ Nitrate of Soda (25 lbs. Nitrogen), -	160 }			
8.	{ Mixed Minerals, as No. 6a, - - -	480 }	15.96	3853	1175
	{ Nitrate of Soda (50 lbs. Nitrogen), -	320 }			
9.	{ Mixed Minerals, as No. 6a, - - -	480 }	19.92	3863	1185
	{ Nitrate of Soda (75 lbs. Nitrogen), -	480 }			
6a.	{ Dissolved Bone-black, } Mixed Minerals, {	320 }	8.00	2624	-54
	{ Muriate of Potash, } - - - - -	160 }			
10.	{ Mixed Minerals, as No. 6a, - - -	480 }	12.44	3638	960
	{ Sulphate of Ammonia (25 lbs. Nitrogen),	120 }			
11.	{ Mixed Minerals, as No. 6a, - - -	480 }	16.88	3857	1179
	{ Sulphate of Ammonia (50 lbs. Nitrogen),	240 }			
12.	{ Mixed Minerals, as No. 6a, - - -	480 }	21.32	4130	1452
	{ Sulphate of Ammonia (75 lbs. Nitrogen),	360 }			
00.	Nothing, - - - - -	—	—	2321	—
6b.	Mixed Minerals, as No. 6a, - - -	480	8.00	3580	902
13.	{ Mixed Minerals, as No. 6a, - - -	480 }	12.02	3133	455
	{ Ammonite (25 lbs. Nitrogen), - - -	192 }			
14.	{ Mixed Minerals, as No. 6a, - - -	480 }	16.06	3248	570
	{ Ammonite (50 lbs. Nitrogen), - - -	384 }			
15.	{ Mixed Minerals, as No. 6a, - - -	480 }	20.10	3414	736
	{ Ammonite (75 lbs. Nitrogen), - - -	576 }			

SOIL TEST WITH FERTILIZERS ON CORN.

TABLE 41.—BY M. H. DEAN, LIME ROCK.

Plot No.	FERTILIZERS PER ACRE.			YIELD PER PLOT.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water		Stover.	Gain or Loss (-) over Noth g Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, -	—	—	58	32	223	7.0	3.3	2230	—
A.	Nitrate of Soda, -	160	3 96	99	41	258	12.0	4.2	2580	1.0
B.	Dis. Bone-black, -	320	4 40	40	40	226	4.8	4.1	2260	-6.3
C.	Muriate of Potash, -	160	3 48	193	51	431	23.3	5.2	4310	13.
D.	{ Nitrate of Soda, - 160 }	320	8 48	116	77	334	14.0	8.0	3340	6.8
	{ Dis. Bone-black, - }									
oo.	Nothing, -	—	—	93	79	255	11.2	8.1	2550	—
E.	{ Nitrate of Soda, - 160 }	160	7 52	225	53	383	27.1	5.5	3830	17.4
	{ Muriate of Potash, - }									
F.	{ Dis. Bone-black, - 320 }	320	8 00	259	55	525	31.2	5.7	5250	21.7
	{ Muriate of Potash, - }									
G.	{ Nitrate of Soda, - 160 }	320	12 00	283	46	540	34.8	4.7	5400	24.3
	{ Dis. Bone-black, - }									
	{ Muriate of Potash, - 160 }	160	16 72	328	33	580	39.5	3.3	5800	27.6
Ca.	{ Nitrate of Soda, - 160 }									
	{ Dis. Bone-black, - 640 }									
	{ Muriate of Potash, - 160 }									

SOIL TEST WITH FERTILIZERS ON COW PEAS.

TABLE 42.—BY THE STATION.

Plot No.	FERTILIZERS.	PER ACRE.		FIELD WEIGHTS. AT CUTTING.		Dry Matter in Crop per Acre.	Green Crop per Acre, 83 %Water.
		Weight of Fertilizers.	Cost of Fertilizers.	Yield per Plot 1-12 Acre	Yield per Acre.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Lbs.
o.	Nothing, - -	—	—	755	9,060	1739	10,230
A.	Nitrate of Soda, -	160	3.96	878	10,536	1863	10,960
B.	Dis. Bone-black, -	320	4.40	824	9,888	1821	10,710
C.	Muriate of Potash, -	160	3.48	1035	12,420	1986	11,680
oo.	Nothing, - -	—	—	785	9,420	1653	9,720
D.	{ Nitrate of Soda, - 160 }	320	8.48	1051	12,612	2196	12,920
	{ Dis. Bone-black, - }						
E.	{ Nitrate of Soda, - 160 }	160	7.52	1228	14,736	2267	13,340
	{ Muriate of Potash, - }						
F.	{ Dis. Bone-black, - 320 }	320	8.00	1312	15,744	2684	15,790
	{ Muriate of Potash, - }						
G.	{ Nitrate of Soda, - 160 }	320	12.00	1486	17,832	2755	16,210
	{ Dis. Bone-black, - }						
	{ Muriate of Potash, - 160 }	160	—	914	10,968	2057	12,100
oo.	Nothing, - -						
X.	{ Stable Manure, - 12000 }	12000	18.80	1303	15,636	2685	15,790
	{ Dis. Bone-black, - 160 }						
Y.	Stable Manure, -	16000	19.20	1474	16,688	2699	15,888

TABLE 43.
SOIL TEST WITH FERTILIZERS ON CORN.
BY ELBERT MANCHESTER, BRISTOL.

Plot No.	FERTILIZERS PER ACRE.			YIELD PER PLOT. (1-10 ACRE.)			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. (11% Water)		Stover.	Gain or Loss (-) Over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, -	—	—	203	53	521	22.1	4.2	5210	—
A.	Nitrate of Soda, -	160	3.96	258	45	518	28.0	3.6	5180	0.4
B.	Dis. Bone-black, -	320	4.40	159	45	522	17.4	3.6	5220	-10.2
C.	Muriate of Potash, -	160	3.48	220	45	567	23.9	3.6	5670	-3.7
D.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }		8.48	338	43	586	36.7	3.4	5860	8.9
E.	{ Nitrate of Soda, - 160 } { Muriate of Potash, - 160 }		7.52	371	34	639	40.3	2.7	6390	11.8
F.	{ Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }		8.00	346	33	586	37.6	2.6	5860	9.0
G.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }		12.00	344	32	705	37.4	2.6	7050	8.8
oo.	Nothing, -	—	—	304	37	564	33.0	3.0	5640	—

TABLE 44.
SOIL TEST WITH FERTILIZERS ON CORN.
BY SPERRY BROTHERS, BOLTON.

Plot No.	FERTILIZERS PER ACRE.			YIELD PER PLOT. (1-10 ACRE.)			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. (11% Water)		Stover.	Gain or Loss (-) Over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, -	—	—	217	22	203	24.4	2.3	2030	—
A.	Nitrate of Soda, -	160	3.96	194	21	204	21.8	2.2	2040	-5.4
B.	Dis. Bone-black, -	320	4.40	208	21	196	23.4	2.2	1960	-3.8
C.	Muriate of Potash, -	160	3.48	188	15	222	21.0	1.5	2220	-6.9
D.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }		8.48	218	24	239	24.5	2.5	2390	-2.4
E.	{ Nitrate of Soda, - 160 } { Muriate of Potash, - 160 }		7.52	229	20	246	25.7	2.1	2460	-1.6
F.	{ Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }		8.00	225	24	281	25.2	2.5	2810	-1.7
G.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }		12.00	281	20	306	31.6	2.1	3060	4.3
H.	Plaster, -	400	1.70	269	21	244	30.2	2.2	2440	3.0
oo.	Nothing, -	—	—	258	29	262	29.0	3.0	2620	—

TABLE 45.
SOIL TEST WITH FERTILIZERS ON CORN.

By WM. E. ALVORD, BOLTON.

Plot No.	FERTILIZERS PER ACRE.			YIELD PER PLOT (1-10 Acre.)			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. 11 % Water		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, - -	—	—	239	26	263	27.5	2.7	2630	—
A.	Nitrate of Soda, -	160	3.96	291	19	290	33.4	1.9	2900	3.0
B.	Dis. Bone-black, -	320	4.40	274	17	273	31.5	1.7	2730	0.9
C.	Muriate of Potash, -	160	3.48	282	21	289	32.5	2.1	2890	2.3
D.	{ Nitrate of Soda, -	{ 160	8.48	309	22	290	35.5	2.2	2900	5.4
	{ Dis. Bone-black, -	{ 320								
E.	{ Nitrate of Soda, -	{ 160	7.52	297	27	305	34.1	2.8	3050	4.6
	{ Muriate of Potash, -	{ 160								
F.	{ Dis. Bone-black, -	{ 320	8.00	313	25	331	36.0	2.6	3310	6.3
	{ Muriate of Potash, -	{ 160								
G.	{ Nitrate of Soda, -	{ 160	12.00	332	27	344	38.3	2.8	3440	7.8
	{ Dis. Bone-black, -	{ 320								
H.	{ Muriate of Potash, -	{ 160	1.70	306	26	298	35.3	2.7	2980	5.7
	{ Plaster, -	{ 400								
oo.	Nothing, - -	—	—	264	40	276	30.3	4.1	2760	—

TABLE 46.
SOIL TEST WITH FERTILIZERS ON CORN.

By C. H. LATHROP, NORTH FRANKLIN.

Plot No.	FERTILIZERS PER ACRE.			YIELD PER PLOT (1-10 Acre.)			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn 11 % Water		Stover.	Gain or Loss (+) over N thing P. S.
				Good.	Poor.		Good.	Poor.		
o.	Nothing, -	Lbs. —	\$ —	Lbs. 241	Lbs. 26	Lbs. 229	Bu. 27.4	Bu. 2.9	Lbs. 2290	Bu. —
A.	Nitrate of Soda, -	160	3.06	164	44	180	18.6	4.5	1800	1.4
B.	Dis. Bone-black, -	320	4.40	199	31	197	22.6	3.2	1970	4.1
C.	Muriate of Potash, -	160	3.48	154	37	170	17.5	3.8	1700	-0.4
D.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }	160 } 320 }	8.48	141	35	175	16.0	3.6	1750	-2.1
E.	{ Nitrate of Soda, - 160 } { Muriate of Potash, - 160 }	160 } 160 }	7.52	116	43	161	13.2	4.4	1610	-4.1
F.	{ Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }	320 } 160 }	8.00	172	32	202	19.5	3.3	2020	1.1
G.	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }	160 } 320 }	12.00	147	31	182	16.7	3.2	1820	1.8
oo.	{ Muriate of Potash, - 160 } Nothing, -	160 } —	—	77	42	133	8.8	4.3	1330	—

TABLE 47.
SOIL TEST WITH FERTILIZERS ON CORN.

By C. A. SHARPE, ABINGTON.

Plot No.	FERTILIZERS PER ACRE.			YIELD PER PLOT. (1-10 ACRE.)			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn. (11% Water)		Stover.	Gain or Loss (-) Over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
		Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
o.	Nothing, - -	—	—	48	25	156	5.9	2.7	1560	—
A.	Nitrate of Soda, -	160	3.96	140	28	194	17.1	3.0	1940	14.4
B.	Dis. Bone-black, -	320	4.40	27	10	160	3.3	1.1	1600	-1.3
C.	Muriate of Potash, -	160	3.48	27	18	217	3.3	1.9	2170	-0.5
D.	{ Nitrate of Soda, -	160 }	8.48	163	18	227	19.9	1.9	2270	16.1
	{ Dis. Bone-black, -	320 }								
E.	{ Nitrate of Soda, -	160 }	7.52	168	22	269	20.5	2.3	2690	17.1
	{ Muriate of Potash, -	160 }								
F.	{ Dis. Bone-black, -	320 }	8.00	23	18	212	2.8	1.9	2120	-1.0
	{ Muriate of Potash, -	160 }								
G.	{ Nitrate of Soda, -	160 }	12.00	132	22	269	16.1	2.3	2690	12.7
	{ Dis. Bone-black, -	320 }								
H.	{ Muriate of Potash, -	160 }	1.70	14	19	153	1.7	2.0	1530	-2.0
	{ Plaster, - - -	400 }								
oo.	Nothing, - -	—	—	8	17	148	1.0	1.8	1480	—

COMPOSITION OF NEW ENGLAND FEEDING STUFFS.

BY CHAS. D. WOODS.

The Reports of the Connecticut Experiment Station for 1888, and previously, have given compilations of the analyses of American feeding stuffs, by Dr. E. H. Jenkins. Experiment Station Bulletin No. 11 of the Office of Experiment Stations of the U. S. Department of Agriculture, contains a detailed compilation by Messrs. Jenkins and Winton of nearly all American analyses which were published before Sept. 1st, 1890. It includes "all the analyses of American feeding stuffs which were accessible to the compilers at the time the work was done, with the exception of those which were so incomplete or so obviously erroneous as to leave no doubt about the propriety of excluding them."

The coarse fodders used in New England are, for the most part, grown in New England. For the past few years this Station has collated for its own use the analyses of New England grown fodders. As we have found these averages to differ considerably from the averages of all American analyses, it has seemed wise to print our compilation.* A few words of explanation of terms, are given with the hope of making the table of analyses more easily understood.

Feeding stuffs are ordinarily divided into two classes: Coarse fodders, hay, stover, ensilage, etc., and concentrated feeds, as the

*The following averages of analyses of Hungarian hay illustrate the differences in composition referred to:

HUNGARIAN HAY.	Water.	Protein.	Fat.	Nit.-free Ex't.	Fiber.	Ash.
	%	%	%	%	%	%
Average of compilations by Jenkins and Winton, - - - - -	7.7	7.5	2.1	49.0	27.7	6.0
Average of New England analyses, -	24.2	7.2	2.3	36.9	23.7	5.7

These differences in composition were largely due to water content, but that they were not entirely due to the different percentages of water is shown by the composition calculated to water-free substance as follows:

HUNGARIAN HAY.	Protein.	Fat.	Nit.-free Ex't.	Fiber.	Ash.
	%	%	%	%	%
Average of compilations by Jenkins and Winton, - - - - -	8.1	2.3	53.1	30.0	6.5
Average of New England analyses, - -	9.6	3.0	48.8	31.1	7.5

grains, gluten and oil meals, wheat bran, etc. This distinction, which depends upon the mechanical condition of the feeding stuffs, while convenient, is arbitrary. It is generally believed that the coarse materials, such as hay, straw, etc., are essential for such animals as chew the cud and for horses. It is certainly of great importance that the coarse fodders of the farm should be profitably utilized, and it may be that the supposed necessity of this class of foods for ruminants is based more upon economical than upon physiological grounds. However this may be, the reason why any or all of the materials commonly used for food are so used, lies in the fact that, whatever their source or mechanical condition, they contain those classes of compounds which are essential for animal life, and consequently the production of milk, butter, beef, or work.

COMPOSITION OF FEEDING STUFFS.

The materials which we feed, so far from being simple in their structure, are composed of many different compounds, which, in the current methods of analysis, are more or less roughly grouped as water, protein, fats, carbohydrates and mineral matters or ash.

The water of a feeding stuff is of no more value for feeding purposes than other water, and hence should not be included among the nutrients or nutritive matter of food. It is quite a common belief among farmers that certain succulent foods such as potatoes, roots and green fodders are more valuable for being watery. A good many exact feeding experiments upon this subject have failed to show that these foods are more digestible and otherwise more valuable for making meat or milk, or for any other purpose of feeding, because of their large water content. Indeed, the presence of water in a food, instead of increasing, reduces the feeding value, since it decreases the amount of nutritive materials (nutrients). A feeding stuff which contains fifty per cent. of water will have only a little more than half the quantity of nutrients that the same material would furnish if the amount of water was reduced to ten per cent. In other words, the less water a feeding stuff contains, other things being equal, the higher will be its feeding value.

The nutrients proper, then, consist of the compounds grouped under protein, fat, carbohydrates, and mineral matters.

The protein consists in part of the albuminoids or albumen like substance, a familiar example of which is the gluten of

wheat. Besides the albuminoids proper, there are other nitrogenous compounds present in vegetable substances, such as the amides, which are less valuable for feeding purposes than are the true albuminoids.

The fat, or, more properly speaking, the "ether extract," includes a large class of compounds dissolved by ether in the analyses made in the laboratory. In addition to the fats or oils proper, the ether extract may contain wax, resins, chlorophyll (the green coloring matter of plants), besides several other less familiar compounds.

The carbohydrates include both the fiber and the "nitrogen-free extract." Fiber is the woody part of a plant, consisting principally of cellulose and lignin. Cellulose is the digestible part of the fiber and is much like starch in its chemical composition and probable feeding value.

The nitrogen-free extract is not directly determined in ordinary analyses, but is found by difference; that is, by subtracting the sum of the percentages of the other ingredients from one hundred per cent. It consists of starch, sugar, gums, and many other substances not so well known.

All the parts of plants contain more or less mineral matter or ash, and generally in more than sufficient amount for feeding purposes, and for this reason it is not usually taken into account in calculating rations. It is, however, of the utmost importance in the proper nutrition of an animal that the ash constituents be furnished in sufficient quantity.

USES OF THE FOOD.

The food supplies the needs of the body in several ways. It is used to form new tissues and fluids and to repair the wastes of the old; it is stored in the body in the form of fat; and it is consumed as fuel, its potential energy being transformed into heat or muscular energy, or other forms of energy required by the body.

It is only recently that we have learned to know in what way the various classes of nutrients of which the food materials are composed, are used in the body. While there is much that remains to be done before we shall have an exact knowledge of this subject, the following statements can be made with considerable certainty:

The protein forms tissues, as muscles, tendon, etc., and fat, and serves as fuel.

The fat forms fatty tissue, not muscle or tendon, and serves as fuel.

The carbohydrates serve as fuel and may be transformed into fat. The amount of carbohydrates which exist as such in the body is very minute, and it might seem as though they would be of very little feeding importance, but they are one of the principle sources of animal heat and of muscular power, and may be transformed into fat, and thus stored in the body for future use.

In supplying the body with fuel the protein, fat and carbohydrates replace each other in nearly exact proportions to their potential energy or fuel value, which is measured by the heat produced when they are burned.*

From experiment it has been found that each .01 pound of protein or carbohydrates yields, when burned, about 18.6 calories of potential energy, and that each .01 pound of fat yields 42.2 calories. In the compilation of analyses of feeding stuffs which follows, the fuel values of the different foods have been obtained by the use of these factors.

The table itself requires little explanation. "Maximum" and "Minimum" represent in each case the largest and the smallest percentage of each ingredient found in any specimen of the material named. Hence, they do not show the composition of any one specimen, but rather the extreme percentages of each ingredient determined in the different specimens analyzed. Of course, they do not foot up to 100 per cent., but those for minimum fall below, and those for the maximum rise above 100. These figures are given in order to indicate, so far as the data will allow, the variations in composition that may be expected in feeding stuffs.

The fuel values of one pound of each of the foods were calculated by the use of factors, as explained above.

The number of analyses of New England grown milling products is doubtless greater than given in the table herewith, but from the analyses as reported, it is in most cases impossible to distinguish between western grown and New England grown milling products. There is appended to the table the average composition of the more commonly fed American milling and waste products as compiled by Dr. Jenkins and Mr. Winton.†

* See Report of this Station for 1890, p. 177.

† Experiment Station Bulletin, No. 11, Office of Experiment Stations, U. S. Department of Agriculture.

TABLE 48.

Minimum, Maximum and Average Composition of New England grown Feeding Stuffs and American Milling Products.

KIND.	No. of Analysis.	IN WATER-FREE SUBSTANCE.						CALCULATED TO WATER CONTENT AT TIME OF SAMPLING.						
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.
<i>Green Fodders, Grasses, Etc.</i>														
Barley fodder, at cutting, -	2	Min., 12.1	2.4	34.6	19.9	8.3	1450	65.1	2.1	.4	5.8	4.3	2.9	245
	2	Max., 13.7	2.5	55.6	25.7	25.2	1765	83.1	4.8	.9	19.4	6.9	4.3	615
	2	Avg., 12.9	2.4	45.1	22.8	16.8	1665	74.1	3.5	.6	12.6	5.6	3.6	430
Hungarian, at cutting, -	9	Min., 6.9	1.7	41.9	28.4	4.3	1750	65.8	2.1	.5	9.1	7.6	1.2	435
	9	Max., 17.1	4.1	51.8	34.7	9.8	1875	78.3	4.7	1.1	16.9	11.2	2.7	610
	9	Avg., 10.9	2.7	47.4	31.7	7.3	1790	72.3	3.0	.7	13.2	8.8	2.0	495
Corn (maize) fodder, dent, at cutting, -	16	Min., 7.6	1.0	42.6	20.4	4.6	1730	70.5	.5	.1	3.0	2.0	.6	110
	16	Max., 18.2	5.4	61.4	34.7	10.6	1875	39.6	3.8	1.6	18.8	11.0	2.5	645
	16	Avg., 12.0	3.2	50.5	27.0	7.3	1800	83.8	1.9	.5	8.5	4.2	1.1	295
Corn (maize) fodder, flint, at cutting, -	34	Min., 7.6	1.7	44.8	17.4	3.8	1710	58.7	1.4	.3	4.3	2.1	.7	170
	34	Max., 17.2	6.7	63.1	32.1	11.3	1865	90.9	4.0	1.7	19.7	13.0	4.7	745
	34	Avg., 10.7	3.4	53.6	25.9	6.4	1820	79.9	2.0	.7	10.8	5.3	1.3	365
Corn (maize) fodder, sweet, at cutting, -	8	Min., 7.9	1.3	45.2	23.9	5.5	1665	80.8	.9	.1	3.2	1.9	.7	115
	8	Max., 13.5	4.2	55.9	30.8	13.8	1820	92.9	2.2	.6	9.2	6.0	2.3	320
	8	Avg., 10.7	2.5	49.8	27.4	9.6	1740	86.5	1.4	.3	6.8	3.7	1.3	235
Meadow fescue (<i>Festuca elatior</i>), at cutting, -	8	Min., 6.9	2.5	41.0	35.0	5.9	1785	69.9	1.8	.7	9.7	7.9	1.6	425
	8	Max., 14.1	3.4	47.3	38.0	8.3	1810	76.3	3.3	.8	14.3	10.6	2.1	545
	8	Avg., 9.1	2.9	45.0	36.0	7.0	1800	73.3	2.4	.8	12.1	9.6	1.8	480
Oat fodder, at cutting, -	2	Min., 7.1	2.0	50.4	32.8	7.0	1770	71.2	1.5	.4	10.8	7.1	1.6	380
	2	Max., 7.1	2.4	50.7	33.1	7.4	1785	78.6	2.0	.7	14.6	9.5	2.0	515
	2	Avg., 7.1	2.2	50.6	32.9	7.2	1775	74.9	1.8	.5	12.7	8.3	1.8	450

Avena elatior, at cutting, -	{	Min.,	4	7.4	3.1	42.8	32.5	7.1	1795	65.9	2.4	1.0	13.4	10.1	2.2	565
	{	Avg.,	4	9.9	3.4	45.0	34.5	7.2	1805	67.8	3.2	1.1	14.5	11.1	2.3	580
Orchard grass, at cutting, -	{	Max.,	11	16.8	4.9	48.2	36.9	9.7	1820	77.8	4.0	1.8	15.5	12.6	3.2	625
	{	Min.,	4	7.6	.9	47.8	30.4	6.7	1750	62.4	1.9	.2	11.3	7.8	1.6	400
Pearl millet, at cutting, -	{	Avg.,	4	7.9	1.8	49.8	33.0	7.5	1765	72.5	2.2	.5	13.7	9.0	2.1	485
	{	Max.,	5	9.7	2.7	50.9	36.9	7.3	1800	76.2	2.8	1.0	21.6	15.7	2.9	775
Red-top, at cutting, -	{	Min.,	2	8.3	2.4	40.1	25.8	6.2	1775	74.7	1.6	.7	5.1	3.3	.6	225
	{	Avg.,	2	12.8	3.9	42.2	32.3	8.8	1790	81.0	1.9	1.4	7.5	7.2	1.0	370
Sweet vernal grass, at cutting, -	{	Max.,	2	11.6	3.8	51.2	31.1	6.1	1835	75.1	2.9	1.0	13.1	7.7	1.5	470
	{	Min.,	2	6.4	2.2	48.9	34.8	5.8	1805	72.6	1.7	.6	13.0	9.2	1.6	475
Tall oat grass, at cutting, -	{	Avg.,	2	7.2	2.3	49.5	35.2	5.8	1805	73.0	1.9	.6	13.4	9.5	1.6	485
	{	Max.,	19	11.9	3.8	53.3	39.7	7.5	1825	78.7	3.7	1.1	23.3	13.6	2.2	825
Timothy, at cutting, -	{	Min.,	4	8.5	3.4	43.7	26.4	5.4	1830	69.9	2.2	.9	10.1	6.3	1.5	425
Wheat fodder, at cutting, -	{	Avg.,	4	10.6	3.7	48.8	30.7	6.2	1835	74.3	2.8	.9	12.6	7.9	1.5	470
	{	Max.,	2	7.7	2.5	51.7	34.2	5.7	1840	70.1	2.5	.8	17.2	11.4	1.7	615
<i>Green Fodders (Legumes).</i>																
Clover, red, at cutting, -	{	Min.,	10	10.4	1.7	38.4	22.5	6.5	1720	47.1	2.3	.4	5.3	2.5	1.3	250
	{	Avg.,	10	16.0	2.8	44.4	28.2	8.6	1765	78.6	3.9	.8	9.0	5.7	2.0	380

TABLE 48.—(Continued.)

KIND.	No. of Analysis.	IN WATER-FREE SUBSTANCE.						CALCULATED TO WATER CONTENT AT TIME OF SAMPLING.									
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.			
		%	%	%	%	%		%	%	%	%	%	%				
<i>Green Fodders (Legumes).</i>																	
<i>(Continued.)</i>																	
Cow pea fodder, at cutting, -	{ Min.,	25	8.3	1.8	35.0	19.9	6.0	1645	78.8	1.7	.3	4.1	3.1	1.2	200		
	{ Max.,	25	21.7	4.6	60.9	27.6	15.1	1755	88.3	3.5	.7	12.9	5.1	2.7	390		
	{ Avg.,	25	17.5	3.2	45.4	22.5	11.4	1725	83.0	2.9	.6	7.8	3.8	1.9	295		
Oat and pea fodder at cutting, -	{ Min.,	5	13.1	2.7	38.4	24.1	8.1	1755	72.9	3.0	.6	5.9	3.7	1.4	285		
	{ Max.,	5	22.9	5.1	44.9	31.2	9.9	1805	84.7	3.5	1.0	12.2	7.7	2.7	475		
	{ Avg.,	5	17.8	3.9	41.7	27.5	9.1	1785	80.3	3.4	.7	8.3	5.5	1.8	350		
Serradella, at cutting, -	{ Min.,	3	12.0	2.1	35.4	26.2	11.5	1695	80.1	2.3	.4	6.4	4.1	1.8	260		
	{ Max.,	3	17.8	2.7	41.4	38.8	11.9	1700	81.6	2.7	.4	7.1	7.7	2.3	335		
	{ Avg.,	3	14.0	2.3	37.5	34.6	11.6	1700	81.7	2.5	.4	6.8	6.5	2.1	310		
Soy bean (<i>Soja hispida</i>) fodder, at cutting, -	{ Min.,	6	8.8	2.5	40.8	19.8	6.4	1740	72.2	2.3	.6	10.7	5.2	1.8	410		
	{ Max.,	6	20.7	8.5	55.4	31.7	11.1	1870	76.8	5.4	2.2	14.3	8.8	2.8	505		
	{ Avg.,	6	13.2	4.4	46.4	26.9	9.1	1795	74.4	3.4	1.1	11.9	6.9	2.3	460		
Vetch fodder, at cutting, -	{ Min.,	3	19.0	1.9	31.6	28.8	9.6	1555	78.2	3.8	.4	5.9	5.0	1.6	390		
	{ Max.,	3	22.6	2.3	35.4	31.7	18.8	1735	83.3	4.1	.4	6.9	6.3	4.1	340		
	{ Avg.,	3	20.7	2.1	33.2	30.2	13.8	1650	81.0	3.9	.4	6.3	5.7	2.7	305		
Vetch and oat fodder, at cutting, -	{ Min.,	7	7.7	2.3	40.1	26.3	7.2	1695	64.8	1.5	.4	5.6	4.7	1.5	235		
	{ Max.,	7	14.8	4.8	50.0	35.7	12.4	1835	86.1	3.6	.9	17.6	10.8	3.3	625		
	{ Avg.,	7	10.8	3.0	44.8	32.4	9.0	1765	76.2	2.6	.7	10.8	7.6	2.1	400		
<i>Cured Fodders, Grasses, Etc. (Hays).</i>																	
Blue (June) grass (<i>Poa pratensis</i>) cured, -	{ Min.,	3	8.8	2.0	43.5	29.6	6.7	1750	6.6	8.2	1.9	39.3	26.8	6.3	1635		
	{ Max.,	3	15.4	4.5	44.9	36.8	8.2	1835	9.6	13.9	4.1	41.9	34.3	7.7	1710		
	{ Avg.,	3	12.4	3.5	44.2	32.6	7.3	1805	7.7	11.4	3.3	40.7	30.1	6.8	1670		

Bromus, - - -	(Min., 2	10.6	3.6	49.0	28.2	6.8	1805	8.4	9.6	3.3	44.8	25.6	6.2	1635
	(Max., 2	11.0	3.8	49.5	29.7	7.9	1820	9.3	10.1	3.4	44.9	27.2	7.2	1665
	(Avg., 2	10.8	3.7	49.2	29.0	7.3	1815	8.8	9.8	3.4	44.9	26.4	6.7	1650
Corn fodder, field cured, -	(Min., 5	5.9	2.0	58.8	21.1	2.9	1815	24.4	2.9	1.2	24.5	8.4	1.7	735
	(Max., 5	10.1	3.1	61.7	28.3	5.1	1865	60.2	6.2	2.0	46.4	21.1	3.8	1410
	(Avg., 5	8.4	2.5	60.5	24.3	4.3	1840	39.5	5.1	1.5	36.6	14.8	2.5	1115
Corn fodder, - - -	(Min., 5	6.2	1.1	53.9	23.0	4.7	1800	6.6	5.8	1.0	47.5	20.9	4.4	1635
	(Max., 5	9.3	2.8	58.9	33.0	6.0	1815	14.8	8.4	2.5	53.4	31.5	5.4	1685
	(Avg., 5	7.5	1.8	56.0	29.5	5.2	1805	9.3	6.9	1.6	50.7	26.8	4.7	1640
Corn stover, - - -	(Min., 10	4.7	1.3	49.0	32.4	5.9	1755	5.5	3.9	1.0	33.3	22.6	4.3	1220
	(Max., 10	9.2	2.7	52.2	36.8	7.8	1815	31.9	6.5	2.2	49.4	31.8	7.2	1690
	(Avg., 10	6.2	2.1	50.7	34.2	6.8	1785	18.2	5.1	1.7	41.5	27.9	5.6	1460
Corn stover, field cured, -	(Min., 163	3.7	1.2	44.7	20.9	3.7	1715	15.4	1.7	.5	13.8	9.1	1.9	515
	(Max., 163	11.3	3.4	63.1	39.2	9.5	1835	71.3	7.8	2.2	53.3	32.2	6.8	1500
	(Avg., 163	6.5	1.8	51.6	33.9	6.2	1785	45.6	3.5	1.0	28.1	19.5	3.3	790
Fescue grass (<i>Festuca elatior</i>), -	(Min., 2	7.5	2.9	50.7	28.7	6.3	1800	11.1	6.7	2.5	44.1	24.9	5.6	1505
	(Max., 2	10.9	3.0	51.8	31.3	6.9	1815	13.0	9.5	2.7	46.1	27.8	6.0	1610
	(Avg., 2	9.2	3.0	51.2	30.0	6.6	1810	12.0	8.1	2.6	45.1	26.4	5.8	1590
Fowl meadow grass (<i>Poa serotina</i>), -	(Min., 3	8.7	2.8	42.3	31.7	7.4	1760	10.4	7.3	2.5	37.7	28.2	6.1	1515
	(Max., 3	14.9	4.0	46.2	33.8	9.5	1820	16.5	13.3	3.3	38.6	29.3	8.5	1585
	(Avg., 3	11.9	3.4	43.6	32.7	8.4	1785	12.6	10.5	2.9	38.0	28.6	7.4	1550
hay, - - -	(Min., 20	5.8	1.7	41.9	29.2	5.1	1745	7.0	5.2	1.5	29.5	19.4	4.6	1160
	(Max., 20	14.2	3.8	53.0	34.7	8.6	1825	34.9	11.3	3.1	48.0	30.7	7.6	1680
	(Avg., 20	9.6	3.0	48.8	31.1	7.5	1790	24.2	7.2	2.3	36.9	23.7	5.7	1360
Hungarian grass, - - -	(Min., 4	6.2	1.4	43.1	31.3	6.6	1755	7.4	5.7	1.3	39.6	28.4	6.1	1605
	(Max., 4	9.8	2.0	52.8	36.9	8.6	1770	9.3	8.8	1.9	48.9	33.9	7.9	1655
	(Avg., 4	8.2	1.8	49.1	33.4	7.5	1765	8.5	7.4	1.7	45.2	30.3	6.9	1615
Italian rye grass, - - -	(Min., 4	7.0	1.8	42.0	34.1	7.2	1750	5.3	6.4	1.6	38.3	28.3	6.4	1510
	(Max., 4	7.9	4.4	49.2	39.7	8.5	1820	16.9	7.5	3.7	45.5	37.5	8.0	1660
	(Avg., 4	7.4	2.6	46.4	35.7	7.9	1775	9.4	6.8	2.3	42.0	32.4	7.1	1605
Meadow fescue, - - -	(Min., 17	6.5	2.0	43.5	27.4	4.1	1800	6.1	5.9	1.9	38.1	23.2	3.6	1420
	(Max., 17	11.9	4.4	56.0	39.7	8.1	1835	21.4	10.4	3.8	50.8	34.7	7.1	1720
	(Avg., 17	9.0	3.3	50.8	30.7	6.2	1825	13.7	7.7	2.9	44.2	26.1	5.4	1575
Mixed hay (from mixed grasses), -	(Min., 17	6.5	2.0	43.5	27.4	4.1	1800	6.1	5.9	1.9	38.1	23.2	3.6	1420
	(Max., 17	11.9	4.4	56.0	39.7	8.1	1835	21.4	10.4	3.8	50.8	34.7	7.1	1720
	(Avg., 17	9.0	3.3	50.8	30.7	6.2	1825	13.7	7.7	2.9	44.2	26.1	5.4	1575

TABLE 48.—(Continued.)

KIND.	No. of Analysis.	IN WATER-FREE SUBSTANCE.						CALCULATED TO WATER CONTENT AT TIME OF SAMPLING.						
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.
		%	%	%	%	%		%	%	%	%	%	%	%
<i>Cured Fodders, Grasses, Etc. (Hays).</i> (Continued.)														
Mixed hay (from mixed grasses), field cured, - - -	46	6.4	3.0	46.5	31.1	4.3	1815	16.1	4.7	2.2	33.3	20.6	3.4	1245
	46	10.9	5.9	54.6	34.9	6.6	1900	33.1	9.0	4.5	43.1	28.4	5.5	1545
	46	8.2	3.7	49.9	32.9	5.3	1850	24.7	6.2	2.7	37.7	24.7	4.0	1390
Oat hay, - - -	8	6.1	2.4	42.0	20.6	4.8	1790	6.2	5.5	2.1	36.2	15.1	3.5	1375
	8	11.6	4.9	58.2	39.0	7.7	1880	26.9	9.9	4.6	53.4	33.6	6.6	1740
	8	8.7	3.3	49.8	31.9	6.3	1820	12.6	7.7	2.8	43.4	28.0	5.5	1590
Oat straw, - - -	3	2.6	1.2	30.1	41.9	2.1	1850	10.0	2.3	1.0	26.4	37.8	1.8	1615
	3	4.0	3.4	46.6	64.0	4.1	1865	12.5	3.5	3.0	42.0	56.8	3.7	1675
	3	3.1	1.9	35.6	56.6	2.8	1855	11.3	2.7	1.7	31.7	50.2	2.4	1645
Oat straw, field cured, - - -	26	3.7	2.4	43.6	34.5	4.1	1810	10.4	3.2	2.0	30.0	28.0	3.5	1225
	26	9.0	3.9	49.6	43.2	6.3	1865	32.4	7.7	3.5	43.5	36.8	5.3	1670
	26	5.7	3.1	47.0	39.1	5.1	1840	15.2	4.8	2.7	39.8	33.2	4.3	1560
Oat grass (<i>Avena elatior</i>), - - -	2	10.5	3.1	44.0	33.3	7.5	1795	10.3	9.4	2.7	39.4	29.9	6.7	1600
	2	11.9	3.3	44.9	34.1	7.5	1800	10.7	10.7	3.0	40.1	30.4	6.7	1615
	2	11.2	3.2	44.4	33.7	7.5	1795	10.5	10.0	2.9	39.7	30.2	6.7	1610
Orchard grass, - - -	13	7.6	2.4	38.3	24.9	7.0	1755	7.4	6.9	2.1	35.3	21.4	5.0	1505
	13	15.5	5.5	54.8	37.1	9.8	1820	16.6	14.3	5.1	47.0	33.0	9.0	1675
	13	9.7	3.8	45.6	32.8	8.1	1800	10.5	8.7	3.4	40.8	29.3	7.3	1610
Pearl millet, - - -	2	7.9	1.9	49.6	34.3	6.7	1750	7.8	7.3	.8	45.6	31.5	6.2	1610
	2	8.1	1.5	49.6	34.3	7.1	1770	8.1	7.5	1.4	45.7	31.6	6.5	1635
	2	8.0	1.2	49.6	34.3	6.9	1760	7.9	7.4	1.1	45.7	31.5	6.4	1625

Red-top (<i>Agrostis vulgaris</i>),	{ Min., Max., Avg.,	15 15 15	6.4 13.3 9.0	1.5 4.8 3.1	46.7 54.7 50.7	26.9 34.1 30.9	4.2 8.3 6.3	1780 1860 1815	5.6 18.1 9.9	5.9 12.3 8.1	1.4 4.0 2.8	38.2 50.4 45.7	24.9 31.8 27.8	3.8 7.7 5.7	1495 1715 1695
Rye straw, - - -	{ Min., Max., Avg.,	3 3 3	7.9 6.1 6.0	3.0 2.4 2.4	45.5 42.4 48.7	47.9 42.0 42.0	9.2 7.1 8.1	1830 1785 1775	12.5 11.2 10.8	7.0 5.4 5.4	2.7 2.1 2.4	41.0 37.6 43.3	43.3 37.4 24.6	8.1 6.3 6.3	1650 1585 1580
Rye grass, - - -	{ Min., Max., Avg.,	2 2 2	12.6 11.8 11.8	2.9 2.8 2.8	50.8 49.7 43.7	27.7 27.6 29.1	8.1 8.1 3.7	1775 1775 1795	11.0 10.9 6.7	11.2 10.5 4.1	2.6 2.5 1.1	45.3 44.3 37.8	24.7 24.6 24.1	7.2 7.2 3.3	1585 1583 1445
Timothy hay, - - -	{ Min., Max., Avg.,	37 37 37	10.7 7.4 7.4	5.8 3.0 3.0	56.2 51.6 45.7	38.5 33.0 28.8	7.1 5.0 4.0	1895 1840 1795	22.1 10.8 8.4	9.7 6.7 5.0	4.6 2.7 1.5	51.1 45.8 39.2	35.8 29.5 24.7	6.3 4.5 3.5	1735 1640 1025
Timothy and red-top, - - -	{ Min., Max., Avg.,	16 16 16	10.5 8.5 8.5	3.6 2.9 2.9	54.7 50.4 46.7	34.5 32.5 28.1	8.0 5.7 5.7	1850 1825 1780	18.9 13.5 9.2	9.0 7.4 15.2	3.3 2.5 2.6	46.9 43.6 44.2	31.1 28.1 21.6	6.9 4.9 7.2	1695 1575 1615
Cured Fodders (<i>Legumes</i>).															
Alfalfa, - - -	{ Min., Max., Avg.,	8 8 8	11.1 18.8 14.8	1.1 4.5 2.2	40.1 51.7 44.2	25.4 34.4 30.5	7.1 10.5 8.3	1740 1810 1755	4.6 17.7 10.3	10.2 16.9 13.3	1.1 3.7 1.9	34.3 47.3 39.6	21.4 32.8 27.5	6.6 8.8 7.4	1450 1675 1575
Clover (alsike), - - -	{ Min., Max., Avg.,	6 6 6	17.3 14.9 10.4	4.2 3.4 1.7	48.2 44.1 38.8	31.9 27.5 20.2	13.4 10.1 6.5	1825 1755 1705	13.9 10.3 5.1	15.9 13.4 9.5	3.9 3.0 1.6	41.5 39.6 32.0	28.0 24.6 18.3	12.2 9.1 6.1	1670 1570 1415
Clover (red), - - -	{ Min., Max., Avg.,	10 10 10	18.5 14.5 10.8	4.6 2.3 3.4	49.7 45.7 44.2	33.7 28.9 30.8	10.5 8.6 7.3	1810 1755 1785	17.5 8.3 16.7	16.8 13.3 9.0	4.3 2.2 2.8	45.8 41.9 36.8	29.3 26.5 25.5	9.5 7.8 6.0	1635 1610 1485
Oat and pea hay, - - -	{ Min., Max., Avg.,	2 2 2	12.4 11.6 11.6	4.9 4.2 3.6	46.8 45.5 43.7	31.3 31.0 26.1	8.2 7.7 5.9	1840 1815 1810	16.9 16.8 13.4	10.3 9.7 11.6	4.1 3.4 3.1	38.9 37.9 35.1	26.1 25.8 21.2	6.8 6.4 5.1	1535 1510 1430
Rowen, - - -	{ Min., Max., Avg.,	8 8 8	17.4 16.1 15.3	4.5 3.9 2.4	47.0 44.9 45.8	29.3 28.0 21.9	8.3 7.1 5.9	1835 1820 1720	21.6 15.3 7.2	14.8 13.6 13.9	3.5 3.3 2.2	40.0 38.1 40.5	25.2 23.7 19.4	7.1 6.0 5.4	1585 1540 1520
Serradella hay, - - -	{ Min., Max., Avg.,	3 3 3	15.3 17.8 16.8	2.4 3.3 2.9	50.2 48.5 46.7	25.1 23.8 23.8	11.7 8.0 8.0	1805 1780 1780	11.7 9.2 9.2	16.6 15.2 15.2	2.9 2.6 2.6	46.0 44.2 44.2	22.9 21.6 21.6	10.3 7.2 7.2	1675 1615 1615

TABLE 48.—(Continued.)

KIND.	No. of Analysis.	IN WATER-FREE SUBSTANCE.						CALCULATED TO WATER CONTENT AT TIME OF SAMPLING.									
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.			
<i>Cured Fodders (Legumes).</i>																	
<i>(Continued).</i>																	
Vetch hay, - - -	{ Min.,	14.4	1.9	31.5	22.3	6.6	1650	8.3	13.1	1.6	26.5	19.7	7.1	1385			
	{ Max.,	26.2	3.4	41.3	30.0	13.8	1820	15.8	23.1	3.0	40.2	28.1	11.6	1620			
	{ Avg.,	19.3	2.6	40.5	28.7	8.9	1755	11.3	17.0	2.3	36.1	25.4	7.9	1555			
Vetch and oat hay, - - -	{ Min.,	11.8	2.8	42.1	34.4	7.7	1775	11.8	10.4	2.3	35.2	28.8	6.8	1110			
	{ Max.,	2	12.6	43.1	34.4	8.2	1790	16.4	10.5	2.6	38.0	30.4	6.8	1200			
	{ Avg.,	12.2	2.9	42.6	34.4	7.9	1785	14.1	10.5	2.4	36.6	29.6	6.8	1155			
<i>Ensilage.</i>																	
Corn (maize) ensilage, - - -	{ Min.,	6.1	2.8	46.5	26.1	5.7	1790	61.6	1.1	.5	7.6	4.5	.9	295			
	{ Max.,	7	10.7	4.3	33.0	7.4	1855	84.0	2.3	1.1	22.2	10.4	2.4	605			
	{ Avg.,	8.4	3.5	52.0	29.7	6.4	1825	79.5	1.7	.7	10.8	6.0	1.3	375			
<i>Seeds, Grains, Etc.</i>																	
Barley grain, - - -	{ Min.,	9.7	1.7	76.9	4.7	3.0	1840	10.3	8.6	1.5	68.9	4.1	2.7	1615			
	{ Max.,	13.6	1.8	80.5	4.7	3.4	1845	11.9	12.3	1.6	70.9	4.2	3.0	1655			
	{ Avg.,	11.6	1.8	78.7	4.7	3.2	1845	11.1	10.5	1.5	69.9	4.2	2.8	1635			
Buckwheat grain, - - -	{ Min.,	4	10.1	2.4	73.2	1.8	1870	11.4	8.6	2.1	64.5	7.8	1.5	1595			
	{ Max.,	4	11.5	2.6	75.7	2.7	1880	14.8	10.2	2.3	64.9	9.4	2.3	1660			
	{ Avg.,	4	10.7	2.5	74.5	2.4	1875	13.1	9.4	2.2	64.7	8.6	2.0	1630			
Corn (maize) grain, sweet, - - -	{ Min.,	11	12.5	4.3	68.8	1.7	1920	6.3	11.1	3.8	61.8	1.6	1.6	1710			
	{ Max.,	11	17.0	10.1	78.3	3.0	2055	10.9	15.3	9.2	68.9	2.8	2.2	1935			
	{ Avg.,	11	14.4	8.6	72.4	2.1	2025	9.2	13.1	7.8	65.7	2.3	1.9	1835			

Corn (maize) grain, white flint,	{ Min.,	76.9	1.4	1.5	1950	7.5	11.4	4.8	70.0	1.3	1.4	1780
	{ Max.,	78.9	1.7	1.7	1975	9.3	13.1	5.8	73.0	1.5	1.6	1815
Corn (maize) grain, yellow dent,	{ Avg.,	78.1	1.5	1.6	1960	8.6	12.0	5.2	71.3	1.4	1.5	1795
	{ Min.,	77.7	1.5	1.5	1935	9.6	11.6	5.1	69.8	1.3	1.3	1640
Corn (maize) grain, yellow dent, field cured, - - -	{ Max.,	82.3	2.4	2.0	1970	15.2	11.6	3.8	73.4	2.2	1.8	1760
	{ Avg.,	80.2	1.8	1.7	1945	10.8	10.1	4.4	71.5	1.7	1.5	1735
Corn (maize) grain, yellow dent, field cured, - - -	{ Min.,	77.9	1.0	1.1	1920	20.3	4.4	1.8	33.5	.6	.7	815
	{ Max.,	85.1	2.7	2.2	1975	57.5	8.6	4.6	66.8	1.8	1.3	1570
Corn (maize) grain, yellow flint, unmerchantable corn (nubbins),	{ Avg.,	81.5	1.7	1.4	1960	35.0	6.5	3.5	53.0	1.1	.9	1275
	{ Min.,	77.0	1.5	1.4	1920	6.1	10.6	3.6	66.0	1.4	1.3	1685
Corn (maize) grain, yellow flint,	{ Max.,	80.8	2.3	2.4	1970	14.2	12.3	5.5	75.6	2.2	2.1	1825
	{ Avg.,	79.3	1.7	1.7	1945	9.1	11.3	4.4	72.1	1.6	1.5	1765
Corn (maize) grain, yellow flint,	{ Min.,	75.5	.9	1.2	1930	4.5	7.9	3.4	64.9	.8	1.0	1570
	{ Max.,	82.6	2.8	2.1	2010	19.6	13.7	7.1	76.7	2.5	1.8	1805
Corn (maize) grain, yellow flint, field cured, - - -	{ Avg.,	79.5	1.6	1.6	2015	10.2	10.6	4.9	71.4	1.4	1.5	1760
	{ Min.,	77.1	1.0	.9	1745	20.4	5.3	2.3	43.7	.7	.6	1050
Oats, grain, - - -	{ Max.,	84.2	2.4	2.3	1990	46.0	10.5	5.3	57.2	1.7	1.6	1560
	{ Avg.,	80.7	1.7	1.6	1955	29.0	7.6	3.8	57.2	1.2	1.2	1230
Oats, grain, - - -	{ Min.,	67.3	9.9	2.9	1905	9.3	8.0	4.4	59.0	8.9	2.6	1685
	{ Max.,	70.8	14.7	4.0	1955	13.5	12.1	5.8	63.2	12.0	3.5	1770
Oats, grain, field cured, - - -	{ Avg.,	68.8	11.0	3.4	1930	10.8	9.8	5.1	61.4	9.9	3.0	1725
	{ Min.,	62.4	6.1	2.7	1830	11.2	11.2	4.5	52.7	5.3	2.2	1475
Oats, grain, field cured, - - -	{ Max.,	68.3	16.0	3.7	1960	18.5	14.9	5.7	60.3	13.6	3.2	1715
	{ Avg.,	65.7	10.1	3.1	1940	14.0	13.0	5.1	56.5	8.7	2.7	1670
Peas, seed, - - -	{ Min.,	57.0	2.0	2.7	1830	11.5	23.5	1.1	50.4	2.5	2.4	1575
	{ Max.,	65.9	6.8	3.5	1855	13.7	28.6	2.1	57.7	6.0	3.3	1630
	{ Avg.,	60.9	4.2	3.2	1845	12.6	26.2	1.5	53.2	3.6	2.9	1605
<i>Milling Products, Etc.</i>												
Buckwheat middlings, - - -	{ Min.,	55.8	2.3	4.7	1930	12.6	23.8	6.0	48.4	2.1	4.1	1685
	{ Max.,	58.1	3.3	5.0	1945	13.2	25.2	6.4	50.6	2.9	4.4	1695
Corn (maize) meal, - - -	{ Avg.,	56.8	2.9	4.9	1940	12.8	24.7	6.2	49.5	2.6	4.2	1690
	{ Min.,	50.2	1.9	1.5	1935	11.4	1.2	0.1	47.7	2.3	1.3	1625
Corn (maize) meal, - - -	{ Max.,	80.4	2.2	1.6	1950	15.0	10.3	5.2	69.1	38.3	2.0	1700
	{ Avg.,	80.3	2.0	1.6	1945	13.6	7.1	3.7	62.1	11.8	1.7	1665

TABLE 48.—(Continued.)

KIND.	No. of Analysis.	IN WATER-FREE SUBSTANCE.						CALCULATED TO WATER CONTENT AT TIME OF SAMPLING.							
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories	
<i>Milling Products, Etc.</i>															
<i>(Continued.)</i>															
Corn (maize) and cob meal, -	2	9.9	4.1	75.7	3.3	1.6	1925	11.8	8.6	3.6	65.3	2.9	1.4	1695	
		10.0	4.6	80.5	8.6	1.7	1940	13.7	8.8	4.1	71.0	7.4	1.4	1715	
		10.0	4.3	78.0	6.0	1.7	1935	12.8	8.7	3.8	68.1	5.2	1.4	1690	
Corn (maize) cob, -	4	1.4	.1	53.8	2.6	1.5	1835	14.5	9.5	3.7	67.1	1.6	1.3	1620	
		12.0	6.0	80.1	43.2	2.4	1965	16.3	9.7	4.3	68.8	1.8	1.4	1670	
		8.3	4.3	72.0	13.4	2.0	1924	15.4	9.6	4.0	68.0	1.7	1.3	1645	
<i>Roots, Gourds, Tubers, Etc.</i>															
Beets, red, -	7	7.8	.6	49.1	4.5	5.8	1640	85.5	1.1	.1	3.8	.9	.7	130	
		19.9	2.5	79.8	13.6	14.9	1780	92.2	1.7	.2	11.3	1.1	1.4	250	
		13.7	1.1	68.6	7.3	9.3	1715	88.5	1.5	.1	8.1	.8	1.0	200	
Beets, sugar, -	15	7.3	.4	61.9	4.8	3.2	1610	80.5	1.1	.1	6.1	.6	.4	160	
		17.4	1.8	81.5	13.0	14.6	1820	90.6	3.2	.2	14.3	1.3	1.5	355	
		11.6	.8	74.8	6.4	6.4	1760	85.6	1.7	.1	10.8	.9	.9	255	
Carrots, -	4	8.0	1.7	67.2	7.6	4.9	1700	87.5	.8	.2	6.7	.8	.6	170	
		9.6	3.9	74.0	10.8	11.2	1860	90.1	1.2	.5	9.3	1.1	1.1	235	
		8.9	2.3	71.3	9.2	8.3	1760	89.3	1.0	.3	7.6	1.0	.8	190	
Mangolds, -	8	7.8	.7	46.8	6.2	7.8	1550	86.9	1.0	.1	2.7	.6	1.0	85	
		26.4	2.6	73.4	10.6	19.1	1730	94.3	1.9	.2	9.6	1.3	1.4	225	
		14.8	1.3	63.5	8.5	11.9	1670	90.2	1.3	.1	6.5	.8	1.1	165	

[illegible]

* From compilation of Analyses of American Feeding Stuffs, by Jenkins & Winton, *loc. cit.*.

TABLE 48.—(Continued.)

KIND.	No. of Analysis.	IN WATER-FREE SUBSTANCE.						CALCULATED TO WATER CONTENT AT TIME OF SAMPLING.							
		Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Calories per Pound.	
<i>Milling and By-Products.</i>															
<i>(Continued.)</i>															
Buffalo gluten feed,*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Min.,	6	13.0	10.5	53.0	5.8	.8	2090	7.8	11.8	9.6	48.8	5.3	.7	1930
	{ Max.,	9	26.5	15.4	63.9	8.5	1.4	2200	9.6	24.2	13.9	57.7	7.9	1.3	1985
Chicago gluten meal,*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	6	22.4	12.5	56.9	7.2	1.0	2135	8.6	20.5	11.4	52.0	6.6	.9	1955
	{ Min.,	3	27.9	5.2	49.8	1.7	.9	1965	7.2	25.9	4.7	45.1	1.6	.8	1785
Cream gluten.*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	3	42.4	12.6	53.7	5.6	1.3	2135	9.1	38.6	11.7	49.8	5.2	1.2	1985
	{ Min.,	3	37.0	14.7	38.4	1.3	.7	2195	7.7	34.1	13.6	35.0	1.2	.6	2025
Starch feed, wet,	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	3	39.3	16.1	42.4	1.4	.8	2225	8.1	36.1	14.8	39.0	1.3	.7	2045
	{ Min.,	12	12.5	3.5	51.1	4.2	.4	1930	62.3	3.6	1.3	18.7	1.6	.1	560
Oat feed,	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	12	22.4	12.6	68.5	14.7	2.0	2130	72.2	9.6	4.4	28.9	4.4	.6	895
	{ Min.,	4	13.8	6.8	61.2	4.0	3.4	1935	6.4	12.6	6.1	56.2	3.7	3.2	1770
Malt sprouts,	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	4	22.0	8.4	68.0	13.6	4.6	1995	9.2	20.0	7.8	63.7	12.5	4.2	1865
	{ Min.,	4	17.3	7.7	64.4	6.6	4.0	1965	7.7	16.0	7.1	59.4	6.1	3.7	1815
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	4	23.7	1.1	51.6	10.5	4.3	1745	7.3	21.0	1.1	45.5	9.3	3.8	1545
	{ Min.,	4	20.3	3.2	56.7	13.6	7.5	1895	12.0	25.9	3.0	50.3	12.0	6.7	1675
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	{ Avg.,	4	25.8	1.9	54.2	11.8	6.3	1790	10.2	23.2	1.7	48.5	10.7	5.7	1605

Brewers' grains, wet,	Min.,	15	18.9	3.6	41.5	10.9	1.2	1830	68.6	4.3	.8	9.6	3.1	.3	400
	Max.,	15	26.6	9.3	56.7	22.5	6.3	1990	79.4	6.9	2.9	15.9	5.6	1.5	620
	Avg.,	15	22.4	6.5	51.5	15.7	3.9	1940	75.7	5.4	1.6	12.5	3.8	1.0	470
Brewers' grains, dried,	Min.,	3	20.5	4.4	52.3	10.9	3.5	1900	6.2	19.3	4.2	46.1	10.2	3.3	1725
	Max.,	3	23.0	7.4	60.7	13.2	4.3	1955	11.9	20.3	6.5	56.8	11.6	3.8	1810
	Avg.,	3	21.7	6.1	56.3	12.0	3.9	1930	8.2	19.9	5.6	51.7	11.0	3.6	1770
Rye bran,	Min.,	7	13.2	2.1	68.6	2.9	3.3	1810	8.2	11.5	1.8	59.8	2.5	2.9	1570
	Max.,	7	19.0	5.6	76.9	4.7	5.2	1915	13.7	16.8	4.9	67.6	4.1	4.5	1675
	Avg.,	7	16.6	3.2	72.1	4.0	4.1	1860	11.6	14.7	2.8	63.8	3.5	3.6	1645
Wheat bran, -	Min.,	88	13.7	1.8	52.1	2.7	2.9	1785	7.4	12.1	1.5	45.5	2.4	2.5	1500
	Max.,	88	20.6	7.8	72.4	17.7	8.4	1900	15.8	18.9	7.0	63.2	15.5	7.3	1735
	Avg.,	88	17.4	4.5	61.3	10.2	6.6	1845	11.9	15.4	4.0	53.9	9.0	5.8	1625
Wheat middlings, -	Min.,	32	11.7	2.3	60.6	1.4	1.6	1850	9.2	10.1	2.1	53.0	1.3	1.4	1620
	Max.,	32	22.8	6.5	79.9	13.9	7.5	1915	16.0	20.0	5.9	70.9	12.7	6.3	1820
	Avg.,	32	17.8	4.5	68.7	5.2	3.8	1895	12.1	15.6	4.0	60.4	4.6	3.3	1675
Buckwheat middlings, -	Min.,	3	27.8	6.3	42.9	2.7	5.0	1915	9.5	25.1	5.7	36.3	2.4	4.4	1635
	Max.,	3	36.2	9.2	58.2	6.6	6.6	1980	16.3	31.3	8.1	52.7	5.7	5.5	1735
	Avg.,	3	33.3	8.1	48.5	4.6	5.5	1950	13.2	28.9	7.1	42.0	4.0	4.8	1690
Cotton seed meal, -	Min.,	35	25.0	9.7	13.7	1.4	6.1	1940	5.8	23.3	8.8	15.7	1.3	5.7	1685
	Max.,	35	53.9	19.4	41.7	12.6	9.6	2200	18.5	50.8	18.0	38.7	10.1	8.8	2040
	Avg.,	35	46.1	14.2	25.8	6.1	7.8	2050	8.2	42.3	13.1	23.6	5.6	7.2	1880
Linseed meal, old process,	Min.,	21	29.5	5.6	33.5	5.2	4.0	1835	5.6	27.7	5.1	28.4	4.7	4.6	1635
	Max.,	21	41.3	12.7	44.8	14.3	8.4	2040	12.4	38.2	11.6	41.9	13.3	8.2	1910
	Avg.,	21	36.2	8.6	39.2	9.7	6.3	1945	9.2	32.9	7.9	35.4	8.9	5.7	1770
Linseed meal, new process,	Min.,	14	29.0	1.5	39.5	8.3	5.5	1765	6.1	27.1	1.3	35.2	7.6	5.0	1530
	Max.,	14	40.9	4.7	51.7	15.2	7.5	1865	13.4	38.4	4.4	48.0	14.0	6.9	1720
	Avg.,	14	36.9	3.3	42.8	10.5	6.5	1820	10.1	33.2	3.0	38.4	9.5	5.8	1635

* In the earlier analyses of gluten meal little account was made of its source. The few analyses of Buffalo, Chicago and cream gluten given here were made by the Connecticut and the Storrs Stations during 1892-93.

THE DIGESTIBILITY OF FEEDING STUFFS.

BY CHAS. D. WOODS.

It is a matter of every-day experience that only a part of the food eaten is actually used by the animal. It is, therefore, of importance in cattle feeding to have a knowledge, not only of the chemical composition of a given food, but of the amounts of the nutrients, which are capable of being assimilated. It is not so much what an animal eats, as that which it digests, that is actually turned to account.

The word digestibility as commonly used has more than one meaning. People often speak of one food as being more digestible than another, when they mean it is more quickly or easily digested. As here used, the term digestibility means the proportion of any given food or food constituent which is digested under usual conditions, without regard to the time needed or the ease of digestion.

DIGESTION EXPERIMENTS—HOW CONDUCTED.

A digestion experiment is managed as follows: Selected animals are fed with the kind of food to be tested, the chemical composition of which has been ascertained by careful analysis. A weighed portion is fed, care being taken to see that none is wasted, and that all the uneaten residues are weighed and analyzed. In this way the exact weights of protein, fat, fiber, nitrogen-free extract and ash eaten are ascertained. The solid excrement of the animal contains the undigested residues. This is carefully collected, dried, weighed, and analyzed, and the amounts of undigested protein, fat, fiber, nitrogen-free extract and ash contained in it are found. The difference between the amounts found in the undigested residues and the amounts contained in the food eaten is taken as a measure of the amounts of the various nutrients which have been digested and assimilated by the animals.

While this experiment seems comparatively simple, it is surrounded by difficulties which render the work laborious and tend to make the results somewhat uncertain.

Many analyses have been made of nearly all of the materials commonly used for food for cattle, and in consequence we have a fairly good knowledge of their composition. A good many experiments upon the digestibility of the different food materials have been made, but these are necessarily much less in number, and also less accurate in their carrying out than are mere analyses. Considering the short time that the experiment stations have been established in this country, quite a large number of digestion experiments upon American feeding stuffs have been made, but by far the larger number of experiments have been made in Europe, and especially in Germany. Just as it has been of great practical importance to make large numbers of analyses of American foods in order that we may know the composition of American feeding stuffs, so it is important to have a large number of accurately conducted digestion experiments upon American feeding materials. The results already obtained are in many instances more valuable for our conditions than are the results of the much larger number of German experiments.

The tables (Nos. 49 and 50) which follow give a summary of the results of digestion experiments up to the years 1891-2. Table 49 is a translation of the summation table prepared by Profs. Dietrich and König,* and it contains the results of all published European digestion experiments obtainable by these very careful and painstaking compilers. A few American studies are also included.

Table 50 contains a tentative summary of the results of American digestion experiments prepared by Professor W. H. Jordan, Director of the Maine Experiment Station, for the Office of Experiment Stations of the U. S. Department of Agriculture. It is here printed by the courteous consent of the Office of Experiment Stations.

The tables require little explanation. In table 49 there are given the minima and maxima figures as well as the averages obtained in the experiments. The first column in each table gives the number of animals experimented with, and the second column the total number of tests of digestibility of the given feeding stuff made with these animals. In the original of table 49 the results are given to the second decimal place, but they are here given to the nearest whole per cent. in each case.

* *Zusammensetzung und Verdaulichkeit der Futtermittel.*

TABLE 49.

*Maximum, Minimum and Average Coefficients of Digestibility of European Feeding Stuffs.**

Reference No.	KIND OF FEEDING STUFF.	No. of Experiments.		No. of Trials.		Organic Matter.		Protein.		Fat.		Nit.-free Substance.		Fiber.	
						%	%	%	%	%	%				
EXPERIMENTS WITH RUMINANTS.															
<i>Green Fodders, Ensilage and Hay.</i>															
1	Pasture grass (cut before May 15), -	{	Min.,	2	4	75	71	63	75	70					
			Max.,	2	4	79	79	68	84	75	73				
			Avg.,	2	4	77	75	66	79	73					
2	Meadow grass in June, - - -		Avg.,	1	2	71	70	62	75	66					
3	Mixed fodder (clover and grass), green,		Avg.,	1	2	75	78	64	78	67					
4	Mixed fodder (clover and grass), hay,		Avg.,	1	2	63	61	63	71	49					
5	Fodder rye, young, green, - -		Avg.,	1	2	-	79	74	71	80					
6	Green sorghum, - - - -		Avg.,	1	1	73	62	85	78	60					
7	Green maize, cut early, - - -		Avg.,	1	1	70	73	75	67	72					
8	Maize ensilage, - - - -	{	Min.,	3	3	61	45	82	66	47					
			Max.,	3	3	63	54	86	72	64					
			Avg.,	3	3	62	48	85	68	56					
9	Maize fodder, cured, - - -	{	Min.,	3	3	62	44	52	64	56					
			Max.,	3	3	68	52	79	68	71					
			Avg.,	3	3	63	48	67	66	64					
10	Red beet tops ensilage, - - -		Avg.,	1	2	57	65	60	54	54					
11	Potato tops (beginning of October),		Avg.,	1	2	48	42	24	60	36					
12	Poplar leaves (beginning of October),		Avg.,	1	2	58	56	79	65	35					
13	Butter cups (<i>Ranunculus acris</i>), -		Avg.,	1	1	57	8	69	67	41					
14	Daisy, white weed (<i>Lucanthemum vulgare</i>), - - - -		Avg.,	1	1	58	58	62	67	46					
15	Comfrey (<i>Symphytum asperrium</i>) hay, - - - -		Avg.,	1	2	69	58	71	85	18					
16	Timothy hay in bloom, - - -	{	Min.,	4	5	50	45	35	58	39					
			Max.,	4	5	67	60	56	72	62					
			Avg.,	4	5	57	49	49	63	50					
17	Orchard grass hay, after blooming,		Avg.,	1	1	56	59	51	54	51					
18	Red-top in bloom, - - - -		Avg.,	1	1	59	60	44	59	61					
19	Blue joint, end of July, - - -		Avg.,	1	1	42	56	37	43	37					
20	Barnyard grass, in milk, hay, - -		Avg.,	1	1	63	62	60	66	63					
21	Wild oat grass (<i>Danthonia spicata</i>) in bloom, hay, - - - -		Avg.,	1	1	61	49	38	62	65					
22	<i>Imperata arundinacea</i> , hay, - - -		Avg.,	1	2	49	52	38	42	56					
23	Couch grass (<i>Triticum ripens</i>) in bloom,		Avg.,	1	1	61	64	60	62	59					
24	Hay from uncultivated lands in Japan,		Avg.,	1	2	53	41	43	44	65					
25	Hay from uncultivated lands in Japan, with more legumes, - - -		Avg.,	1	2	49	24	41	41	63					
26	Hay from mixed grasses, best quality,	{	Min.,	18	48	61	60	45	58	53					
			Max.,	18	48	79	73	68	76	80					
			Avg.,	18	48	67	65	57	68	63					

* Taken from *Zusammensetzung und Verdaulichkeit der Futtermittel* by Dr. Th. Dietrich and Dr. J. König, Berlin, 1891

TABLE 49.—(Continued.)

Reference No.	KIND OF FEEDING STUFF.	No. of Experiments.	No. of Trials.	Organic Matter.	Protein.	Fat.	Nit.-free Substance.	Fiber.
	EXPERIMENTS WITH RUMINANTS.			%	%	%	%	%
	<i>Green Fodder, Ensilage and Hay.—(Cont'd.)</i>							
27	Hay from mixed grasses, medium quality, - - - - -	{ Min., 35 94 Max., 35 94 Avg., 35 94	{ 50 67 61	{ 49 67 57	{ 15 70 53	{ 53 73 64	{ 51 71 60	{ 51 71 60
28	Hay from mixed grasses, poor quality, - - - - -	{ Min., 10 28 Max., 10 28 Avg., 10 28	{ 46 59 56	{ 35 60 50	{ 10 57 49	{ 64 65 59	{ 46 64 56	{ 46 64 56
29	Rowen hay, - - - - -	{ Min., 6 30 Max., 6 30 Avg., 6 30	{ 60 71 64	{ 54 68 62	{ 28 56 46	{ 63 74 67	{ 61 68 64	{ 61 68 64
30	Red clover, green, before bloom, -	{ Min., 1 2 Max., 2 4 Avg., 2 4	{ 74 72 71	{ 74 76 74	{ 65 75 71	{ 83 82 79	{ 60 52 57	{ 60 52 57
31	Red clover, green, beginning to bloom, - - - - -	{ Min., 2 4 Max., 2 4 Avg., 2 4	{ 68 65 61	{ 72 70 64	{ 66 64 53	{ 73 70 71	{ 60 49 44	{ 60 49 44
32	Red clover, green, full bloom and past, - - - - -	{ Min., 7 17 Max., 7 17 Avg., 7 17	{ 59 67 63	{ 59 71 66	{ 54 74 65	{ 63 76 70	{ 45 54 50	{ 45 54 50
33	Red clover hay, best quality, - -	{ Min., 10 21 Max., 10 21 Avg., 10 21	{ 52 57 56	{ 48 59 54	{ 33 63 53	{ 57 69 64	{ 38 52 46	{ 38 52 46
34	Red clover, hay, medium quality, -	{ Min., 3 6 Max., 3 6 Avg., 3 6	{ 67 68 64	{ 78 83 81	{ 37 54 45	{ 65 77 72	{ 32 47 41	{ 32 47 41
35	Alfalfa, in bloom, green, - -	{ Min., 3 6 Max., 3 6 Avg., 3 6	{ 57 62 62	{ 70 83 80	{ 30 51 41	{ 65 71 69	{ 34 46 41	{ 34 46 41
36	Alfalfa, carefully dried, - - -	{ Min., 8 26 Max., 8 26 Avg., 8 26	{ 54 67 61	{ 71 83 76	{ 26 58 46	{ 53 72 68	{ 34 49 42	{ 34 49 42
37	Alfalfa hay, early bloom, best quality, - - - - -	{ Min., 4 10 Max., 4 10 Avg., 4 10	{ 55 59 57	{ 66 73 68	{ 49 56 53	{ 61 65 63	{ 39 48 45	{ 39 48 45
38	Alfalfa hay, full bloom, medium quality, - - - - -	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 57 55 55	{ 78 73 73	{ 50 32 32	{ 65 65 65	{ 35 37 37	{ 35 37 37
39	Alfalfa, carefully dried,* - -	{ Min., 1 2 Max., 2 4 Avg., 2 4	{ 54 56 54	{ 72 49 64	{ 43 35 76	{ 54 63 67	{ 45 44 74	{ 45 44 74
40	Alfalfa hay,* - - - - -	{ Min., 2 4 Max., 2 4 Avg., 2 4	{ 56 63 59	{ 49 64 73	{ 35 55 60	{ 63 74 67	{ 44 51 64	{ 44 51 64
41	Alfalfa hay, overdried (<i>Brennheu</i>),*	{ Min., 2 4 Max., 2 4 Avg., 2 4	{ 54 63 59	{ 49 64 73	{ 35 55 60	{ 63 74 67	{ 44 51 64	{ 44 51 64
42	Alsike clover, in full bloom, - -	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 59 66 62	{ 73 73 70	{ 51 67 67	{ 42 78 74	{ 36 45 46	{ 36 45 46
43	White clover hay, - - - - -	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 59 66 62	{ 73 73 70	{ 51 67 67	{ 42 78 74	{ 36 45 46	{ 36 45 46
44	Sanfoin, early bloom, green, - -	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 59 66 62	{ 73 73 70	{ 51 67 67	{ 42 78 74	{ 36 45 46	{ 36 45 46
45	Sanfoin hay, carefully dried, - -	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 59 66 62	{ 73 73 70	{ 51 67 67	{ 42 78 74	{ 36 45 46	{ 36 45 46
46	Sanfoin hay, overdried (<i>Brennheu</i>),	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 59 66 62	{ 73 73 70	{ 51 67 67	{ 42 78 74	{ 36 45 46	{ 36 45 46
47	Sanfoin ensilage, - - - - -	{ Min., 1 2 Max., 1 2 Avg., 1 2	{ 59 66 62	{ 73 73 70	{ 51 67 67	{ 42 78 74	{ 36 45 46	{ 36 45 46

* Nos. 39, 40 and 41 are results of experiments upon different portions of the same alfalfa differently cured.

TABLE 49.—(Continued.)

Reference No.	KIND OF FEEDING STUFF.				No. of Experiments.	No. of Trials.	Organic Matter.	Protein.	Fat.	Nit.-free Substance.	Fiber.
	EXPERIMENTS WITH RUMINANTS.						%	%	%	%	%
	<i>Green Fodder Ensilage and Hay.—(Cont'd.)</i>										
48	Serradella, in bloom, hay,	-	-	Avg.,	1	2	62	75	65	63	50
49	Serradella, in seed, hay,	-	-	Avg.,	1	2	47	63	66	48	37
50	Vetch, before bloom, hay,	-	-	Avg.,	1	6	65	76	60	66	54
51	Lupin, hay,	-	-	Avg.,	1	2	—	74	30	62	73
				Min.,	2	4	58	63	14	59	46
52	Soy bean, hay,	-	-	Max.,	2	4	63	76	48	71	58
				Avg.,	2	4	61	69	30	66	53
	<i>Straw, etc.</i>										
				Min.,	2	3	45	18	27	36	52
53	Wheat straw, -	-	-	Max.,	2	3	48	26	58	40	59
				Avg.,	2	3	46	23	36	39	56
				Min.,	3	9	40	21	21	29	47
54	Rye straw, -	-	-	Max.,	3	9	51	29	41	52	73
				Avg.,	3	9	48	25	29	39	63
				Min.,	5	9	49	25	14	33	50
55	Oat straw, -	-	-	Max.,	5	9	53	50	51	55	66
				Avg.,	5	9	51	40	32	47	58
				Min.,	2	5	50	22	38	49	54
56	Barley straw, -	-	-	Max.,	2	5	56	26	43	59	58
				Avg.,	2	5	53	25	42	54	56
57	Maize stover, -	-	-	Avg.,	1	1	—	37	28	40	52
				Min.,	2	4	43	41	37	27	55
58	Rice straw, -	-	-	Max.,	2	4	53	47	52	38	61
				Avg.,	2	4	47	45	47	32	57
				Min.,	3	5	51	45	49	64	36
59	Bean straw, -	-	-	Max.,	3	5	63	54	60	73	53
				Avg.,	3	5	55	49	57	68	43
60	Pea straw, -	-	-	Avg.,	1	2	59	61	46	64	52
61	Lupin straw, -	-	-	Avg.,	1	2	—	38	30	65	51
				Min.,	2	4	52	37	58	62	32
62	Soy bean straw, -	-	-	Max.,	2	4	59	62	64	71	43
				Avg.,	2	4	55	50	60	66	38
63	Soy bean pods, -	-	-	Avg.,	1	2	63	44	57	73	51
				Min.,	2	4	29	24	49	43	10
64	Extracted hops, -	-	-	Max.,	2	4	41	39	77	53	26
				Avg.,	2	4	37	31	64	48	17
	<i>Roots and Tubers.</i>										
				Min.,	4	24	73	44	—	83	—
65	Potatoes, -	-	-	Max.,	4	24	97	88	—	99	—
				Avg.,	4	24	86	61	—	90	—
				Min.,	3	18	80	52	—	92	—
66	Red beet, -	-	-	Max.,	3	18	96	90	—	100	—
				Avg.,	3	18	88	77	—	96	—

TABLE 49.—(Continued.)

Reference No.	KIND OF FEEDING STUFF.					No. of Experiments.	No. of Trials.	Organic Matter.	Protein.	Fat.	Nit.-free Substance.	Fiber.
EXPERIMENTS WITH RUMINANTS.												
Roots and Tubers.—(Cont'd.)												
67	Sugar beet,	-	-	-	-	{ Min.,	2 28	81	34	—	90	—
						{ Max.,	2 28	100	100	—	100	—
68	Turnips,	-	-	-	-	{ Avg.,	2 28	88	62	—	95	—
69	Swedish turnip,	-	-	-	-	{ Avg.,	1 8	78	57	—	88	—
						{ Avg.,	1 2	96	62	93	99	100
Grain, Seeds and Fruits.												
70	Oats,	-	-	-	-	{ Min.,	11 39	62	68	68	65	2
						{ Max.,	11 39	82	94	100	94	47
						{ Avg.,	11 39	71	78	84	77	26
71	Barley,	-	-	-	-	{ Min.,	2 4	81	63	78	87	—
						{ Max.,	2 4	91	77	100	96	—
						{ Avg.,	2 4	86	70	89	92	—
72	Maize (Indian corn),	-	-	-	-	{ Min.,	4 12	88	64	73	90	46
						{ Max.,	4 12	93	84	99	99	100
						{ Avg.,	4 12	91	76	86	93	58
73	Dari,	-	-	-	-	{ Avg.,	1 2	86	65	70	91	51
74	Field beans,	-	-	-	-	{ Min.,	8 29	76	77	56	82	25
						{ Max.,	8 29	100	100	100	100	99
						{ Avg.,	8 29	89	88	82	92	72
75	Peas,	-	-	-	-	{ Avg.,	1 2	90	89	75	93	66
76	Lupin,	-	-	-	-	{ Min.,	6 12	81	85	71	75	77
						{ Max.,	6 12	99	96	96	100	100
						{ Avg.,	6 12	89	90	82	83	91
77	Lupin, steamed and not extracted,	-	-	-	-	{ Avg.,	1 2	92	92	90	89	—
78	Lupin, steamed and extracted,	-	-	-	-	{ Avg.,	1 2	97	94	94	84	—
79	Lupin, in natural condition,	-	-	-	-	{ Avg.,	1 2	81	87	71	76	77
80	Lupin, strongly steamed,	-	-	-	-	{ Avg.,	1 2	68	67	84	66	69
81	Vetch,	-	-	-	-	{ Avg.,	1 2	92	88	92	100	—
82	Soy beans,	-	-	-	-	{ Avg.,	1 2	85	87	94	62	—
83	Linseed,	-	-	-	-	{ Min.,	2 7	68	81	78	39	1
						{ Max.,	2 7	91	100	90	81	100
						{ Avg.,	2 7	77	91	86	55	60
84	Horse chestnuts,	-	-	-	-	{ Avg.,	1 1	100	60	85	93	—
85	Acorns,	-	-	-	-	{ Avg.,	1 2	88	83	88	91	62
86	Carot bean (<i>Johannisbrod</i>),	-	-	-	-	{ Avg.,	1 2	94	68	54	95	—
By-products or Wastes.												
87	Wheat bran,	-	-	-	-	{ Min.,	6 48	63	51	50	70	—
						{ Max.,	6 48	85	100	90	88	58
						{ Avg.,	6 48	71	78	72	76	30
88	Spelt (<i>Triticum spelta</i>) bran,	-	-	-	-	{ Avg.,	2 3	90	73	88	91	59
89	Rye bran,	-	-	-	-	{ Avg.,	1 4	—	41	—	61	—
90	Gluten meal from wheat,	-	-	-	-	{ Avg.,	1 2	91	88	46	92	100
91	Gluten meal from maize (corn),	-	-	-	-	{ Avg.,	1 1	—	85	76	94	34
92	Rice (fodder) meal,	-	-	-	-	{ Avg.,	1 2	89	77	89	100	67
93	Rice (fodder), poor quality,	-	-	-	-	{ Avg.,	1 2	66	45	83	84	33

TABLE 49.—(Continued.)

Reference No.	KIND OF FEEDING STUFF.						No. of Experiments.	No. of Trials.	Organic Matter.	Protein.	Fat.	Nit.-free Substance.	Fiber.
EXPERIMENTS WITH RUMINANTS.													
<i>By-Products or Wastes.—(Cont'd.)</i>													
								%	%	%	%	%	%
94	Malt sprouts, - - - - -	{	Min.,	4	9	64	73	43	58	32			
			Max.,	4	9	82	100	100	94	95			
			Avg.,	4	9	75	81	68	76	64			
95	Brewers' grains, fresh, - - -	{	Min.,	1	2	63	73	84	64	39			
			Max.,	2	7	54	62	66	51	21			
			Avg.,	2	7	62	73	87	74	64			
96	Brewers' grains, dried, - - -	{	Min.,	2	7	54	62	66	51	21			
			Max.,	2	7	72	73	87	74	64			
			Avg.,	2	7	62	69	81	63	39			
97	Beet diffusion residue, dried, - -	{	Min.,	2	6	—	63	—	85	84			
			Max.,	2	10	74	80	87	60	23			
			Avg.,	2	10	88	90	94	96	93			
98	Linseed oil meal, linseed cake, -	{	Min.,	2	10	81	86	90	80	50			
			Max.,	2	10	81	86	90	80	50			
			Avg.,	2	10	81	86	90	80	50			
99	Linseed oil meal, without fat, - -	{	Min.,	1	8	71	82	91	73	—			
			Max.,	2	7	48	65	60	66	—			
			Avg.,	2	7	48	65	60	66	—			
100	Rape seed oil cake, - - - -	{	Min.,	2	7	48	65	60	66	—			
			Max.,	2	7	79	92	94	85	34			
			Avg.,	2	7	79	81	79	76	8			
101	Rape seed oil meal, without fat, -	{	Min.,	1	1	68	84	—	85	—			
			Max.,	2	4	85	90	86	93	16			
			Avg.,	2	4	85	90	86	93	16			
102	Peanut oil cake, - - - -	{	Min.,	1	2	78	76	100	77	62			
			Max.,	2	8	50	72	86	46	2			
			Avg.,	2	8	60	77	93	60	24			
103	Cocoonut oil cake, - - - -	{	Min.,	2	8	50	72	86	46	2			
			Max.,	2	8	60	77	93	60	24			
			Avg.,	2	8	54	74	90	51	16			
104	Cotton seed oil cake, with hulls, -	{	Min.,	2	8	50	72	86	46	2			
			Max.,	2	8	60	77	93	60	24			
			Avg.,	2	8	54	74	90	51	16			
105	Cotton seed oil cake, without hulls, -	{	Min.,	2	4	80	84	85	66	—			
			Max.,	2	4	81	89	100	84	—			
			Avg.,	2	4	81	87	95	76	—			
106	Sesame (<i>Sesam indicum</i>) oil cake, -	{	Min.,	1	4	77	90	90	57	31			
			Max.,	1	4	77	90	90	57	31			
			Avg.,	1	4	77	90	90	57	31			
107	Palm nut oil cake, - - - -	{	Min.,	1	2	75	77	94	79	54			
			Max.,	2	3	89	87	88	92	72			
			Avg.,	2	3	89	87	88	92	72			
108	Palm nut oil meal (fat removed), -	{	Min.,	2	3	96	100	100	99	95			
			Max.,	2	3	91	95	95	94	82			
			Avg.,	2	3	91	95	95	94	82			
109	Sunflower seed oil cake, - - - -	{	Min.,	1	4	76	90	88	71	31			
			Max.,	1	4	76	90	88	71	31			
			Avg.,	1	4	76	90	88	71	31			
<i>Animal Foods.</i>													
110	Cows' milk, - - - - -	{	Min.,	5	5	97	91	100	93	—			
			Max.,	5	5	99	97	100	99	—			
			Avg.,	5	5	98	94	100	98	—			
111	Flesh meal (ground meat), - - -	{	Min.,	2	3	92	94	96	—	—			
			Max.,	2	3	96	97	100	—	—			
			Avg.,	2	3	93	96	99	—	—			
112	Blood meal, - - - - -	{	Min.,	1	2	63	62	100	100	—			
			Max.,	1	2	63	62	100	100	—			
			Avg.,	1	2	63	62	100	100	—			
113	Fish meal, - - - - -	{	Min.,	1	2	—	90	76	—	—			
			Max.,	1	2	—	90	76	—	—			
			Avg.,	1	2	—	90	76	—	—			
EXPERIMENTS WITH HORSES.													
114	Best mixed hay, - - - - -	{	Min.,	3	4	54	59	10	60	42			
			Max.,	3	4	62	69	43	69	57			
			Avg.,	3	4	58	64	22	66	48			
115	Medium mixed hay, - - - - -	{	Min.,	11	14	40	46	7	49	21			
			Max.,	11	14	60	66	43	63	48			
			Avg.,	11	14	50	59	18	58	39			

TABLE 49.—(Continued.)

Reference No.	KIND OF FEEDING STUFF.				No. of Experiments.	No. of Trials.	Organic Matter.	Protein.	Fat.	Nit.-free Substance.	Fiber.
							%	%	%	%	%
EXPERIMENTS WITH HORSES.—(Cont'd.)											
116	Poor mixed hay, - - - -	Min.,	4	12	42	43	6	45	34		
		Max.,	4	12	51	62	33	61	49		
		Avg.,	4	12	46	55	24	52	38		
117	Red clover hay, - - - -	Min.,	4	5	49	51	27	61	35		
		Max.,	4	5	55	60	31	67	41		
		Avg.,	4	5	51	56	29	64	37		
118	Alfalfa, - - - - -	Min.,	4	6	55	70	6	67	33		
		Max.,	4	6	62	77	30	71	44		
		Avg.,	4	6	58	73	14	70	40		
119	Wheat straw, - - - - -	Min.,	3	6	1	12	—	4	3		
		Max.,	3	6	56	44	—	56	54		
		Avg.,	3	6	21	28	66	28	18		
120	Spelt (<i>Triticum spelta</i>) straw, -	Avg.,	1	1	25	23	20	18	30		
121	Potatoes, - - - - -	Avg.,	1	1	93	88	—	99	9		
122	Carrots, - - - - -	Avg.,	1	1	87	99	—	94	—		
123	Oats, - - - - -	Min.,	16	34	61	68	50	70	1		
		Max.,	16	34	80	94	88	84	56		
		Avg.,	16	34	69	80	71	75	29		
124	Barley, - - - - -	Avg.,	1	1	87	80	42	87	100		
125	Maize (corn), - - - - -	Min.,	2	2	87	75	59	90	41		
		Max.,	2	2	91	78	63	94	100		
		Avg.,	2	2	89	76	61	92	41		
126	Field beans, - - - - -	Avg.,	1	5	87	86	13	94	65		
127	Peas, - - - - -	Avg.,	1	1	80	83	7	89	8		
128	Lupin (extracted), - - - -	Avg.,	1	1	72	94	27	51	51		
EXPERIMENTS WITH SWINE.											
129	Potatoes, - - - - -	Min.,	5	9	91	57	—	97	28		
		Max.,	5	9	96	88	—	99	83		
		Avg.,	5	9	93	72	—	98	55		
130	Barley (hulled), - - - -	Min.,	6	13	78	67	51	87	14		
		Max.,	6	13	85	81	77	91	29		
		Avg.,	6	13	82	75	65	90	15		
131	Maize (corn), hulled, - - -	Min.,	3	4	90	84	74	93	17		
		Max.,	3	4	95	89	79	96	57		
		Avg.,	3	4	92	86	76	95	40		
132	Rice (hulled), - - - - -	Avg.,	2	2	98	86	70	100	—		
133	Peas (hulled), - - - - -	Min.,			88	84	36	95	55		
		Max.,			93	91	69	99	89		
		Avg.,			91	88	49	97	68		
134	Rye bran, - - - - -	Avg.,	1	2	67	66	58	75	9		
135	Cocoonut oil cake, - - - -	Avg.,	1	2	80	73	83	89	60		
136	Flesh meal, - - - - -	Avg.,	1	8	92	97	86	—	—		
137	Blood meal, - - - - -	Avg.,	1	1	72	72	—	92	—		
138	May beetle (<i>Maikaefer</i>), - -	Avg.,	1	6	57	69	83	—	—		
139	Sour milk (loppered), - - -	Avg.,	1	1	95	96	95	99	—		

TABLE 50.
*Coefficients of Digestibility of American Feeding Stuffs as determined
 by American Experiments.**

Reference No.	KIND OF FEEDING STUFF.	No. of Experiments.	No. of Trials.	Dry Matter.	Organic Matter.	Protein (N. $\times$ 6.25).	Fat.	Nitrogen-free Extract.	Fiber.
	EXPERIMENTS WITH RUMINANTS.			%	%	%	%	%	%
1	Pasture grass, - - -	3	4	71	—	71	63	74	75
2	Soiling rye, - - -	1	2	74	—	79	74	71	80
3	Corn ensilage, - - -	10	18	64	—	46	80	67	67
4	Soiling clover, - - -	1	2	66	—	67	64	78	53
5	Sorghum, - - -	1	2	61	—	40	67	71	43
6	Timothy hay (all experiments), -	11	27	58	—	49	55	63	53
7	Timothy hay (early cut), -	3	5	61	62	57	56	64	59
8	Timothy hay (late cut), -	3	6	53	54	45	58	60	46
9	Hungarian hay, - - -	1	6	64	66	61	58	66	68
10	Blue-joint hay, - - -	2	3	54	56	63	45	56	54
11	Orchard grass hay, - - -	2	3	56	—	59	54	55	60
12	Red-top hay, - - -	2	3	59	61	61	50	62	61
13	Witch grass hay, - - -	2	3	61	62	59	57	65	63
14	Wild oat grass hay, - - -	2	2	64	65	58	50	65	68
15	Mixed hay (clover and timothy),	2	3	55	—	42	54	57	49
16	Clover hay (red), - - -	2	7	53	54	52	48	61	47
17	Alsike clover hay (cut in bloom),	1	3	62	63	66	50	71	53
18	White clover hay (in late bloom),	1	1	66	67	73	51	69	61
19	Alfalfa hay, - - -	2	3	—	—	73	51	68	46
20	Corn fodder (whole plant), -	19	37	67	—	58	71	69	70
21	Corn stover, - - -	1	4	62	—	52	52	64	66
22	Oat straw, - - -	1	2	50	51	—	37	52	57
23	Potatoes, - - -	1	3	77	78	44	13	91	—
24	Roots, - - -	4	8	88	92	84	77	95	80
25	Corn meal, - - -	1	2	85	—	58	92	87	—
26	Pea meal, - - -	1	2	87	88	83	54	94	26
27	Malt sprouts, - - -	1	1	67	67	80	—	68	33
28	Cotton seed meal, - - -	1	2	81	81	89	100	68	—
29	Wheat bran, - - -	2	4	59	63	78	73	66	—
30	Wheat middlings, - - -	1	2	75	77	79	85	83	—
31	Gluten meal, - - -	1	2	87	89	87	88	91	—
32	Cotton seed hulls, - - -	1	1	36	—	25	81	40	27
	EXPERIMENTS WITH SWINE.								
33	Whole corn (kernel), - -	1	1	82	83	69	46	89	38
34	Corn meal, - - -	1	1	89	91	86	82	94	29
35	Corn and cob meal, - -	1	1	76	77	76	82	84	28

* From a compilation made by Prof. W. H. Jordan, Director of the Maine Agricultural Experiment Station, for the Office of Experiment Stations of the U. S. Department of Agriculture, by whose courtesy this table is here printed.

An examination of table 49, in which there are given minima and maxima as well as average digestion coefficients, will show that in many instances there is a great range in the digestibility of the same kinds of feeding stuffs. This was to have been expected, since there are so many modifying elements entering into a digestion experiment. The kinds of animals used, their breeds, ages, and especially differences of individual animals, greatly modify the results. The methods of harvesting and curing, the period of growth at which the plant is cut, the length of time kept after curing, the quantities fed, whether fed green or cured, and the method of preparation of the food, all affect the digestibility of the feeding stuff and, moreover, mixtures of different feeds do not seem to be digested in the same way as the same feeds would be if fed alone. It follows from this, taken together with the comparatively small number of accurate digestion experiments thus far conducted, that it would not do to follow absolutely the figures of either tables 49 or 50.

Looking at tables 49 or 50, one will find that different species of grasses have in some instances very different digestibility. While it is probably true that there are specific differences in digestibility, it is very much to be doubted if the results of experiments thus far obtained would warrant us in assigning definite different coefficients of digestibility to different species of coarse fodders. In table 51, which follows, there is given a summary of the average coefficients of digestibility of tables 49 and 50. In this table (51), instead of arranging the coarse fodders under their specific names, materials which are more or less alike are classed together. Thus, under green fodders, the different kinds of grass, rye and allied plants are grouped together. The numbers in the table immediately following the words European and American refer to the reference numbers in the respective tables (49 and 50) from which the averages were obtained. It is of considerable interest to note that while individual experiments (see table 49) upon the same species have quite different range of digestibility, that the average of results obtained in the groups, in both European and American experiments, accord fairly well. There are also given in this table (51) the factors which were used in calculating the pounds of digestible matter in different feeding stuffs, as given in table 52. In the instances in which simply inspection of the table will not show how the factors used in table 52 were obtained, explanations are given in foot notes.

TABLE 51.

Average Coefficients of Digestibility of Different Classes of Feeding Stuffs as Ascertained by European and American Feeding Experiments, and the Factors Used in Computing Table 52.

KIND OF FEEDING STUFF.	No. of Tests.	Organic Matter.	Protein.	Fat.	Nitrogen- free Extract.	Fiber.
GREEN FODDERS.		%	%	%	%	%
<i>Grass, Rye, Etc.</i>						
European (Nos. 1-3, 5 and 6), -	11	74	74	69	76	71
American (Nos. 1 and 2), -	6	—	74	67	73	83
Factors used in table 52, -	—	—	74	67	73	83
<i>Corn Fodder.</i>						
European (No. 1), -	1	70	73	75	67	72
Factors used in table 52,* -	—	—	74	67	73	83
<i>Clover, Alfalfa, Etc.</i>						
European (Nos. 30-32, 35 and 34),	18	66	74	57	75	47
American (No. 4), -	2	—	67	64	78	53
Factors used in table 52, -	—	—	67	64	78	53
ENSILAGE.						
<i>Corn Ensilage.</i>						
European (No. 8), -	3	62	48	85	68	56
American (No. 3), -	18	—	46	80	67	67
Factors used in table 52, -	—	—	46	80	67	67
DRY COARSE FODDERS.						
<i>Hay of Grasses.</i>						
European (Nos. 16-23, and 26-28),	183	61	58	53	63	60
American (Nos. 6 and 9-14), -	47	62	54	54	63	55
Factors used in table 52, -	—	—	54	54	63	55
<i>Corn Fodder.</i>						
European (No. 9), -	3	63	48	67	66	64
American (No. 20), -	37	—	58	71	69	70
Factors used in table 52, -	—	—	58	71	69	70
<i>Corn Stalks (Stover).</i>						
European (No. 57), -	1	—	37	28	40	52
American (No. 21), -	4	—	52	52	64	66
Factors used in table 52, -	—	—	52	52	64	66
<i>Mixed Hay, Clover and Timothy.</i>						
American (No. 15), -	3	—	42	54	57	49
Factors used in table 52, -	—	—	42	54	57	49
<i>Rowen Hay.</i>						
European (No. 29), -	30	64	62	46	67	64
Factors used in table 52, -	—	—	62	46	67	64
<i>Clover, Alfalfa, Etc., Hay.</i>						
European (Nos. 33, 34, 36-43, 45,						
46 and 48-50), -	109	57	68	52	66	46
American (Nos. 16, 17, 18 and 19),	14	57	61	49	65	46
Factors used in table 52, -	—	—	61	49	65	46

* Same as for grass, rye, etc.

TABLE 51.—(Continued.)

KIND OF FEEDING STUFF.	No. of Tests.	Organic Matter.	Protein.	Fat.	Nitrogen- free Extract.	Fiber.
<i>Oat Straw.</i>		%	%	%	%	%
European (No. 55), - - -	26	51	40	32	47	58
American (No. 22), - - -	2	51	—	37	52	57
Factors used in table 52, - -	—	—	40	37	52	57
<i>TUBERS AND ROOTS.</i>						
<i>Potatoes.</i>						
European (No. 65), - - -	24	86	61	—	90	—
American (No. 23), - - -	3	78	44	13	91	—
Factors used in table 52, - -	—	—	50	75*	91	33†
<i>Roots.</i>						
European (Nos. 68-69), - - -	10	82	58	—	90	—
American (No. 24), - - -	8	92	84	77	95	80
Factors used in table 52, - -	—	—	84	77	95	80
<i>MILLING AND BY-PRODUCTS.</i>						
<i>Corn Meal.</i>						
European (No. 72), - - -	12	91	76	86	93	58
American (No. 25), - - -	2	—	58	92	87	—
Factors used in table 52, - -	—	—	76†	92	87	58
<i>Corn and Cob Meal.</i>						
American, - - - - -	1	77	76	82	84	28
Factors used in table 52, - -	—	—	76	82	84	28
<i>Pea Meal.</i>						
European (No. 75), - - -	2	90	89	75	93	66
American (No. 26), - - -	2	88	83	54	94	26
Factors used in table 52, - -	—	—	83	54	94	26
<i>Gluten Meal from Corn.</i>						
European (No. 91), - - -	1	—	85	76	94	34
American, - - - - -	2	89	87	88	91	—
Factors used in table 52, - -	—	—	87	88	91	33†
<i>Malt Sprouts.</i>						
European (No. 94), - - -	9	75	81	68	76	64
American (No. 27), - - -	1	67	80	—	68	33
Factors used in table 52, - -	—	—	81	68	76	64
<i>Brewers' Grains.</i>						
European (Nos. 95 and 96), - -	9	62	69	81	63	39
Factors used in table 52, - -	—	—	69	81	63	39
<i>Wheat Bran and Middlings.</i>						
European (No. 87), - - -	48	71	78	72	76	30
American (No. 29), - - -	6	68	78	76	72	—
Factors used in table 52, - -	—	—	78	76	72	33†
<i>Cotton Seed Meal.</i>						
European (No. 105), - - -	4	81	87	95	76	—
American (No. 28), - - -	2	81	89	100	68	—
Factors used in table 52, - -	—	—	89	100	68	33†
<i>Linseed Meal.</i>						
European (No. 98), - - -	10	81	86	90	80	50
Factors used in table 52, - -	—	—	86	90	80	50

* Assumed. † American figures were so low European were used. (See corn and cob meal.)

THE CALCULATION OF RATIONS.

BY CHAS. D. WOODS.



In the preceding pages there have been summarized the results of analyses of the principal feeding stuffs used in New England and the results of digestion experiments showing in how far the animals are able to digest the nutrients furnished them in the different foods. It is only a few years since this subject was first introduced into America. The first at all full explanation of the composition and the digestibility of feeding stuffs and feeding standards ever given on this side of the Atlantic, or indeed in the English language, was presented before the winter meeting of the Connecticut State Board of Agriculture less than twenty years ago.* Since that time, many of our best farmers have come to a pretty clear understanding of the German feeding standards, and have learned to calculate the amounts of nutrients in the rations which they feed their stock. Perhaps, on the whole, those of us who have adopted these ideas have taken the matter a little too seriously, since there is danger of assuming that feeding standards are absolute, and that the calculations of a ration are merely questions of arithmetic.

At the present, the value of any food used in cattle-feeding is usually estimated by calculations based upon (*a*) more or less perfect knowledge of the chemical composition of the feeding stuff; that is, the percentages of protein, of fat, of carbohydrates, including fiber, and the ash; (*b*) upon the digestibility of these different ingredients in the class of food used, as observed in actual feeding experiments, and (*c*) upon the amounts of the digestible nutrients, as ascertained by feeding experiments and practical experience, which are needed for the proper nutrition of animals of different kinds, or fed for different purposes.

In table 48, pp. 144-155, there are given the average percentage composition of New England feeding stuffs, and figures showing

*Results of late European Experiments on the Feeding of Cattle, by W. O. Atwater, Report Connecticut Board of Agriculture, 1874, pp. 131-180.

the range of variation in composition. It is, I suspect, customary for those who use such tables to calculate their rations by assuming the materials they use to be of average composition and average digestibility. The great variability in composition of feeding stuffs, which a glance at the table will show, points out the unwisdom of blindly assuming a given feeding material to be of average composition. If it were practicable, the best method, when deciding upon a ration to be used, would be to have analyses made of the materials to be fed; but since this is not generally practicable, the farmer is left largely to his own judgment as to the quality of the food. Tables showing the range in composition will help to a better estimate of the probable composition of a given feeding stuff, when used with a knowledge of conditions of growth, than can be obtained in any way except by actual analysis.

In estimating whether a feed is above or below the average composition and digestibility, some of the more important conditions affecting composition and digestibility should be taken into account. They may be summed up as follows:

Crops of grain, and fodder plants other than legumes, grown with nitrogenous fertilizers, will usually contain more protein than those grown with only mineral fertilizers.

Fodders are equally digestible, whether fed green or dry, provided there is no loss in curing.

Quick curing without overdrying, and with a minimum of handling, reduces loss of leaves and other fine portions of the plant. Hay thus cured will usually be richer in protein and in fats than if there is much loss in curing. The protein and fat are also more digestible in such hays than in those that are not carefully cured.

The method of preparation of a fodder, *i. e.*, whether steamed before feeding or not, or whether fed hot or cold, so far as the experiments show, produces no effect upon the digestibility.

As a rule, the older the plant, the less percentages of protein and fat and the more of fiber it contains. Also, the protein, fats, and carbohydrates are less digestible in old than in young plants. This points out the importance of comparatively early cutting. Probably the best time for cutting most plants used for hay is when they are in early bloom.

Long keeping reduces digestibility and is attended by loss of actual dry matter.

The chief thing to be observed in the use of concentrated feeds is to keep the ration narrow and not to supply too large a quantity of fat. Practically it is probably unwise to feed a ration whose nutritive ratio is greater than that of one to seven, or at the most one to eight. Some of the more recent experiments with milch cows seem to indicate that even a narrower ration than the ordinary standard, 1 to 5.4, can be used with profit.

Reference has been made (p. 165) to the fact that there is more or less uncertainty attending the use of coefficients of digestibility, but as a good guess is a better guide than blind ignorance, so digestion factors help us to a much better understanding of the value of a food than is possible without an attempt to take digestibility into account. Because our facts are not sufficient to warrant absolutely definite conclusions, it does not follow that we should not live up to all the light we have. The coefficients of digestibility suggested in table 51, in which the average results obtained in European and American digestion experiments are compared, are perhaps as good as any we have as yet. Twenty years ago we had almost no knowledge of the composition of American feeding stuffs. The number of analyses were so few that no attempt was made to compile them for practical use. In the past twenty years nearly 5,000 specimens of American feeding stuffs have been analyzed, and we know within quite definite limits what the composition of any given feeding stuff is. It is to be hoped and expected that the next two decades will see such additions made to our knowledge of digestibility that we may then be able to speak as confidently of the coefficients of digestibility as we now do of percentages of total nutrients.

In table 52 the attempt is made to calculate the weights of the different digestible nutrients and the calories of potential energy which would be supplied by a pound of each of the different kinds of feed most used in Connecticut. The figures here given were obtained by multiplying the averages of the analyses of different feeding stuffs given in table 48, p. 144, by the factors (digestion coefficients) given in table 51, p. 166.

TABLE 52.

Weights of Total Organic Matter and of Digestible Nutrients and Calories of Potential Energy in Digestible Nutrients of One Pound of Different Feeding Stuffs of Average Composition and Digestibility.

KIND OF FEEDING STUFF.	Total Organic Matter.	DIGESTIBLE NUTRIENTS.*				
		Total Digestible Nutrients.	Protein.	Fat.	Carbo- hydrates.	Fuel Value.
<i>Green Fodders at Cutting.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
Barley fodder, - - -	.223	.168	.026	.004	.138	320
Hungarian fodder, - - -	.257	.196	.022	.005	.169	375
Corn fodder (dent), - - -	.170	.129	.015	.004	.110	250
Corn fodder (flint), - - -	.188	.143	.015	.005	.123	280
Corn fodder (sweet), - - -	.122	.092	.010	.002	.080	175
Oat fodder, - - -	.233	.177	.013	.003	.161	335
Orchard grass, - - -	.274	.210	.021	.007	.182	405
Pearl millet, - - -	.254	.194	.016	.003	.175	370
Red-top, - - -	.319	.244	.017	.005	.222	465
Rye fodder, - - -	.180	.137	.014	.009	.114	275
Timothy, - - -	.300	.229	.019	.005	.205	440
Wheat fodder, - - -	.242	.184	.021	.006	.157	355
Clover, - - -	.194	.131	.026	.005	.100	255
Cow pea vines, - - -	.151	.104	.019	.004	.081	205
Oat and pea fodder, - - -	.179	.129	.024	.005	.100	250
Vetch, - - -	.163	.108	.026	.003	.079	210
Vetch and oats, - - -	.217	.157	.018	.005	.134	305
<i>Corned Fodders and Hays.</i>						
Blue (June) grass, - - -	.855	.502	.062	.018	.422	975
Corn fodder, - - -	.860	.589	.040	.011	.538	1120
Corn stover (stalks), - - -	.762	.486	.027	.009	.450	925
Fowl meadow, - - -	.800	.469	.057	.016	.396	910
Hungarian, - - -	.701	.413	.039	.012	.362	800
Hay mixed grasses, - - -	.809	.480	.042	.016	.422	930
Oat hay, - - -	.819	.484	.042	.015	.427	935
Oat straw, - - -	.805	.425	.019	.010	.396	815
Orchard grass, - - -	.822	.483	.047	.018	.418	940
Red-top, - - -	.844	.500	.044	.015	.441	965
Timothy, - - -	.847	.502	.036	.015	.451	970
Timothy and red-top, - - -	.816	.483	.040	.013	.430	930
Alfalfa, - - -	.823	.474	.081	.009	.384	905
Clover (alsike), - - -	.806	.467	.082	.015	.370	905
Clover (red), - - -	.839	.485	.081	.010	.394	925
Rowen hay, - - -	.787	.506	.084	.015	.407	975
<i>Ensilage.</i>						
Corn ensilage, - - -	.192	.126	.008	.006	.112	250
<i>Roots, Etc.</i>						
Carrots, - - -	.099	.090	.008	.002	.080	170
Mangolds, - - -	.087	.080	.011	.001	.068	150
Pumpkins, - - -	.133	.114	.027	.019	.068	255
Potatoes, - - -	.199	.169	.012	.001	.156	315
Ruta-bagas, - - -	.099	.090	.009	.002	.079	170
Turnips, - - -	.088	.078	.008	.002	.068	150

* The factors (digestion coefficients) used are those of table 51.

TABLE 52.—(Continued.)

KIND OF FEEDING STUFF.	Total Organic Matter.	DIGESTIBLE NUTRIENTS.*				
		Total Digestible Nutrients.	Protein.	Fat.	Carbo- hydrates.	Fuel Value.
<i>Milling and By-Products.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
Corn meal, - - - -	.836	.713	.070	.035	.608	1410
Corn and cob meal, - - -	.858	.684	.066	.031	.587	1345
Pea meal, - - - -	.869	.692	.168	.006	.518	1300
Hominy chops, - - - -	.864	.694	.074	.068	.552	1450
Buffalo gluten feed, - - -	.906	.774	.178	.100	.496	1675
Chicago gluten meal, - - -	.912	.794	.263	.082	.449	1670
Cream gluten, - - - -	.912	.803	.314	.130	.359	1800
Starch feed (wet), - - -	.343	.264	.046	.025	.193	550
Oat feed, - - - -	.886	.762	.139	.062	.561	1565
Malt sprouts, - - - -	.841	.637	.188	.012	.437	1215
Brewers' grains (wet), - - -	.233	.144	.037	.013	.094	300
Brewers' grains (dried), - - -	.882	.550	.137	.045	.368	1130
Wheat bran, - - - -	.823	.568	.120	.030	.418	1130
Wheat middlings, - - - -	.846	.602	.122	.030	.450	1190
Cotton seed meal, - - - -	.846	.685	.376	.131	.178	1580
O. P. linseed meal, - - - -	.851	.681	.283	.071	.327	1435
N. P. linseed meal, - - - -	.841	.667	.286	.027	.354	1305

* The factors (digestion coefficients) used are those of table 51.

Keeping in mind that there is no such thing as a "best" ration, that individual animals vary in their needs, and in the extent to which they utilize the nutrients in their food, and that any one sample of a feeding stuff is generally either better or poorer than the average of all the samples of the same kind of feeding stuff that have been analyzed, we may venture to use such a table as the preceding (52).

As an illustration of the way such a table may be used, the detailed calculation of a ration follows.

At a farmers' institute, held in Bristol in the winter of 1893-4, a milkman, whose milk was tested by the Babcock method, said that he was feeding per 1000 pounds live weight as follows: Corn meal, 5 pounds; Buffalo gluten feed, 5 pounds; cotton seed meal, 2½ pounds; hay, 5 pounds; and ensilage, 40 pounds. Assuming the different feeding stuffs to be of average composition and digestibility, the ration may be calculated, from figures given in table 52, as follows:

EXAMPLE OF CALCULATING A RATION BY USE OF TABLE 52.

*Kinds and Amounts of Feeding Stuffs Fed by a Bristol Milkman,
and their Estimated Nutrients.*

FEEDING STUFF.		DIGESTIBLE NUTRIENTS.			
Kind.	Amount.	Protein.	Fat.	Carbo- hydrates.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Calories.
Corn meal, - - 5	{	(.070×5) .350	(.035×5) .175	(.608×5) 3.040	(1410×5) 7050
Buffalo gluten feed, 5	{	(.178×5) .890	(.100×5) .500	(4.96×5) 2.480	(1675×5) 8375
Cotton seed meal, - 2½	{	(.376×2½) .940	(.131×2½) .328	(.178×2½) .444	(1580×2½) 3950
Hay, - - - 5	{	(.042×5) .210	(.016×5) .080	(.422×5) 2.110	(930×5) 4650
Ensilage, - - 5	{	(.008×40) .320	(.006×40) .240	(.112×40) 4.480	(250×40) 10,000
Total, - - -	—	2.7	1.3	12.6	34,025
Nutritive ratio,* 1:		- - - - -	-	$\frac{(1.3 \times 2\frac{1}{2}) + 12.6}{2.7} = 5.7$	

* Multiply the weight of digestible fat by two and a half, and add the product thus obtained to the weight of digestible carbohydrates and divide this sum by the weight of digestible protein. The quotient thus found is called the nutritive ratio.

Our knowledge of rations in general and for milch cows in particular, and its limitation, is referred to at some length in pages 94-101 of the present Report. Different as the "standards" for feeding milch cows, given in page 100, are from each other, it is probably true that 75 per cent. or more of the feeders of dairy stock in America would find that their herds would give better returns if they should try to make the rations which they feed conform to either of the four rations there suggested. This would follow not more from the improvement in the ration fed, than from the increased attention to details in care and handling which would follow better attention to feeding. The study of the individual animal which would be apt to be the outcome of this increased attention would doubtless, in most instances, result in an attempt to vary the ration of that particular animal so as to conform more nearly to its needs.

STUDIES OF DIETARIES.

BY H. B. GIBSON AND C. D. WOODS.

REPORTED BY W. O. ATWATER.



Accounts of studies of dietaries of families and a boarding house, by the Station, have been given in previous reports, as follows:

- | | |
|----------------------------|---------------------------|
| 1. A boarding house.* | 5. A machinist's family.† |
| 2. A chemist's family.* | 6. A mason's family.† |
| 3. A jeweler's family.† | 7. A carpenter's family.† |
| 4. A blacksmith's family.† | 8. A carpenter's family.† |

Five dietaries have since been studied and are here reported. They are those of:

9. The family of the Station Agriculturist in winter.
10. A mason's family (the same as No. 6).
11. A carpenter's family (the same as No. 8).
12. A college students' club.
13. The family of the Station Agriculturist in summer.

The general plan of the investigation included an account of the amounts and composition of all food materials of nutritive value in the house at the beginning, purchased during and remaining at the end of the experiment, and of all the kitchen and table wastes. The amounts of different food materials on hand at the beginning and received during the experiment were added; from this sum the amounts remaining at the end were subtracted. This gave the amount of each material actually used. From the amount thus obtained and the composition of each material, as shown by analysis, the amounts of the nutritive ingredients were estimated. From these were subtracted the amounts of nutrients in the waste, and thus the amounts of nutrients actually eaten were learned.

Account was kept of the meals taken by the different members of the family, and by visitors. The number of meals for one man, to which the total number actual meals taken was equivalent, was estimated upon the basis of the potential energy, as has

* Report of this Station, 1891, pp. 90-106.

† Report of this Station, 1892, pp. 135-162.

been done in previous investigations here.* These energy equivalents, which are stated below, are somewhat arbitrary, and require revision in the light of accumulating inquiry. It has seemed best, however, to use the same figures here as in the previous reports and postpone the change until these dietaries may be summarized with others in a later publication.

Estimated Relative Quantities of Potential Energy in Nutrients Required by Persons of Different Classes.

Man at moderate work,	-	-	-	-	-	-	-	10
Woman at moderate work,	-	-	-	-	-	-	-	8
Child, 15 to 6 years old,	-	-	-	-	-	-	-	7
Child, 6 to 2 years old,	-	-	-	-	-	-	-	5
Child, under 2 years old,	-	-	-	-	-	-	-	2½

EXPLANATION OF TABLES.

The figures in the first table of each dietary (tables 53, 55, 57, 59 and 61), giving the actual amounts of food and of nutrients in the food used during the dietary, are based upon the weights of the food materials as they were purchased and used; that is, they include bone and other refuse, except where specified.

The first three columns in the table contain the percentages of protein, fat and carbohydrates used in computing the amounts of those nutrients in the different food materials. In all cases where the composition was not fairly well known from previous analyses, specimens of the food materials actually used in the dietary, or specimens as nearly identical as possible, were analyzed. The cases in which special analyses were made in connection with these dietaries are indicated in the table by placing the letter *a* after the name of the material. The weights of the water-free table and kitchen wastes, and their composition, are given in the last line of the table. Exactly what is included in these wastes is explained in the foot note on page 97 of the Report of this Station for 1891.

The third (last) table in each dietary (tables 54, 56, 58, 60 and 62) gives the nutrients and potential energy in food purchased, in table and kitchen wastes, and in the portion actually eaten. The estimates of animal and vegetable nutrients in the waste are computed as below described, and those of potential energy (fuel value of nutritive ingredients) as explained in an earlier Report.†

Table 63 summarizes the results of the thirteen dietary studies which have been made by the Station.

* See especially 17th Annual Report of the Massachusetts Bureau of Statistics of Labor, pp. 239-329.

† Report of this Station, 1890, p. 174.

DIETARY OF THE STATION AGRICULTURIST'S FAMILY IN WINTER.

The study began January 15, 1893 and continued 30 days.

The family was as follows:—

Man (agriculturist), 32 years old, light work.

Woman, 26 years old (assumed = .8 of one man).

Woman (servant), 35 years old (assumed = .8 of one man).

The meals taken were equivalent to 274 meals, or 91 days for one man.

TABLE 53.

Food Materials and Table and Kitchen Wastes in Dietary of the Station Agriculturist's Family During Thirty Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOOD.	%	%	%	Grams.*	Grams.	Grams.	Grams.
<i>Beef.</i>							
Sirloin, - - -	15.5	17.4	—	10,860	1,683	1,890	—
Round steak, - -	17.7	14.5	—	5,100	902	740	—
Shin, - - -	13.6	1.4	—	2,240	305	31	—
Corned brisket, - -	13.7	31.1	—	2,890	396	899	—
Corned, canned, - -	26.7	17.1	—	540	144	236	—
Total, - - -	—	—	—	21,630	3,430	3,796	—
<i>Mutton, Etc.</i>							
Part of leg mutton, -	15.2	17.5	—	790	120	138	—
Fore quarter lamb, -	14.7	21.0	—	2,500	368	525	—
Total, - - -	—	—	—	3,290	488	663	—
<i>Pork.</i>							
Spare rib, - - -	14.1	25.3	—	2,640	372	668	—
Lard, - - -	—	99.8	—	2,040	—	2,036	—
Salted, - - -	.9	82.8	—	80	1	66	—
Total, - - -	—	—	—	4,760	373	2,770	—
<i>Fish, Etc.</i>							
Herring, - - -	10.0	5.9	—	230	23	14	—
Cod, - - -	10.6	.2	—	840	89	2	—
Haddock, - - -	8.2	.2	—	880	72	2	—
Smelts, - - -	10.0	1.0	—	740	74	7	—
Halibut, - - -	15.1	4.4	—	680	103	3	—
Salmon, canned, - -	20.9	13.9	—	450	94	63	—
Oysters, - - -	6.3	1.6	4.0	910	57	15	36
Total, - - -	—	—	—	4,730	512	106	36

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 53.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.—(Con.)	%	%	%	Grams.*	Grams.	Grams.	Grams.
<i>Dairy Products, Etc.</i>							
Milk, - - -	3.6	4.0	4.7	23,760	855	950	1,117
Cream, - - -	2.5	18.8	4.1	500	13	94	20
Butter, - - -	—	85.0	—	4,650	—	3,952	—
Total, - - -	—	—	—	28,910	868	4,996	1,137
Eggs, - - -	12.6	10.5	—	1,930	243	202	—
Total animal food, -	—	—	—	65,250	5,914	12,533	1,173
VEGETABLE FOOD.							
Wheat flour (a), -	12.6	.9	74.2	17,720	2,233	159	13,148
Corn meal and samp, -	9.2	3.8	70.6	1,770	163	67	1,480
Oat meal, - - -	14.7	7.1	68.4	960	141	68	657
Wheat germs, - - -	11.9	1.7	74.8	1,590	189	27	1,189
Rice and macaroni, -	7.4	.4	79.4	540	40	2	429
Crackers, - - -	9.3	13.1	69.0	1,560	145	204	1,076
Graham crackers, -	9.8	13.6	69.7	450	44	61	314
Sugar, - - -	—	—	100.0	10,770	—	—	10,770
Molasses, - - -	—	—	72.0	2,040	—	—	1,469
Honey, - - -	.8	—	77.9	680	5	—	462
Dried beans, - - -	20.7	1.8	60.4	370	77	7	223
Potatoes (15 % refuse),	2.1	.1	17.9	26,070	547	26	2,060
Parsnips, - - -	1.3	.7	16.2	3,250	42	23	526
Squash (edible), - -	.9	.2	10.1	4,900	44	10	495
Onions (edible), - -	1.4	.3	10.1	410	6	1	41
Turnips (edible), - -	1.2	.2	8.2	1,900	23	4	156
Apples (edible), - -	.3	.4	15.9	7,710	23	30	1,227
Total vegetable food,	—	—	—	82,690	3,722	689	35,722
Total animal and vegetable food purchased,	—	—	—	147,940	9,636	13,222	36,895
Table and kitchen wastes (a), - -	35.0	28.9	32.4	1,963	687	567	636

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 54.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of an Agriculturist's Family.

FOOD MATERIALS.				NUTRIENTS.			Potential Energy.
				Protein.	Fat.	Carbo- hydrates.	
				Grams.*	Grams.	Grams.	Calories.
<i>For Family, 30 Days.</i>							
Food purchased,	-	Animal, -	-	5,914	12,533	1,173	145,610
		Vegetable, -	-	3,722	689	35,722	168,130
Waste, -	-	Total, -	-	9,636	13,222	36,895	313,740
		Animal, -	-	616	556	—	7,700
Food actually eaten,	-	Vegetable, -	-	71	11	636	3,000
		Total, -	-	687	567	636	10,700
Food actually eaten,	-	Animal, -	-	5,298	11,977	1,173	137,910
		Vegetable, -	-	3,651	678	35,086	165,130
		Total, -	-	8,949	12,655	36,259	303,040
<i>Per Man, Per Day.</i>							
Food purchased,	-	Animal, -	-	65	137	13	1,590
		Vegetable, -	-	41	8	392	1,860
Waste, -	-	Total, -	-	106	145	405	3,450
		Animal, -	-	6	6	—	80
Food actually eaten,	-	Vegetable, -	-	1	—	7	35
		Total, -	-	7	6	7	115
Food actually eaten,	-	Animal, -	-	59	131	13	1,510
		Vegetable, -	-	40	8	385	1,825
		Total, -	-	99	139	398	3,335
<i>Percentages of Total Food Purchased.</i>							
Food purchased,	-	Animal, -	-	61.4	94.8	3.2	46.4
		Vegetable, -	-	38.6	5.2	96.8	53.6
Waste, -	-	Total, -	-	100.0	100.0	100.0	100.0
		Animal, -	-	6.4	4.3	—	2.5
Food actually eaten,	-	Vegetable, -	-	.7	—	1.7	.9
		Total, -	-	7.1	4.3	1.7	3.4
Food actually eaten,	-	Animal, -	-	55.0	90.6	3.2	43.9
		Vegetable, -	-	37.9	5.1	95.1	52.7
		Total, -	-	92.9	95.7	98.3	96.6

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A MASON'S FAMILY.

The study began April 1, 1892, and continued twenty-eight days. The family (the same as in 6*) was as follows:—

Man about 28 years old (mason), at work three of the four weeks.

Woman of about same age (assumed = .8 of one man).

Child 1 year old (assumed = .25 of one man).

The meals taken were equivalent to 168 meals, or 56 days for one man.

TABLE 55.

Food Materials and Table and Kitchen Wastes in Dietary of a Mason's Family during Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOOD.	%	%	%	Grams.†	Grams.	Grams.	Gr'ns.
<i>Beef.</i>							
Round steak, free from bone,	19.0	13.6	—	1,900	361	258	—
Shoulder clod, - - -	17.0	13.7	—	2,130	362	292	—
Shank, free from bone, -	22.7	2.3	—	450	102	10	—
Shank, with bone, - -	13.6	1.4	—	1,980	269	28	—
Bologna sausage, - -	18.6	15.8	.2	950	177	150	2
Total, - - - -	—	—	—	7,410	1,271	738	2
<i>Veal.</i>							
Shoulder, - - - -	16.6	8.7	—	2,000	532	174	—
<i>Pork.</i>							
Chops, - - - -	14.1	25.3	—	2,760	389	698	—
Shoulder, - - - -	13.5	30.4	—	2,070	279	629	—
Pigs' feet, pickled, -	10.7	10.1	—	1,930	207	195	—
Sausage, - - - -	12.2	42.4	1.3	500	61	212	6
Salt pork, - - - -	.9	82.8	—	1,390	12	1,151	—
Lard, - - - -	—	99.8	—	710	—	708	—
Total, - - - -	—	—	—	9,360	948	3,593	6
<i>Fish, Etc.</i>							
Canned salmon, - - -	20.9	13.9	—	1,400	293	195	—
Fresh cod, - - - -	10.6	.2	—	450	48	1	—
Salt cod, - - - -	16.0	.4	—	450	72	2	—
Sardines and anchovies, -	25.3	12.7	—	910	230	116	—
Total, - - - -	—	—	—	3,210	643	314	—

* Report of this Station, 1892, pp. 158-161.

† 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 55.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.—(Cont'd.)	%	%	%	*Grams.	Grams.	Grams.	Grams.
<i>Dairy Products, Etc.</i>							
Whole milk (a), - - -	3.8	4.0	5.1	17,320	658	693	883
Skim milk (a), - - -	2.4	.3	4.1	25,230	606	76	1,034
Butter, - - - - -	—	85.0	—	1,590	—	1,352	—
Cheese, - - - - -	28.0	35.3	2.1	610	171	215	13
Total, - - - - -	—	—	—	44,750	1,435	2,336	1,930
Eggs, - - - - -	12.6	10.5	—	4,550	573	478	—
Total animal food, - - -	—	—	—	71,280	5,402	7,633	1,938
VEGETABLE FOOD.							
Wheat flour (a), - - -	13.0	.8	73.4	5,410	703	43	3,971
Rye flour (a), - - -	8.8	1.0	77.6	2,350	207	24	1,824
Buckwheat (a), - - -	7.1	1.0	73.4	240	17	2	176
Oatmeal, - - - - -	15.2	7.0	68.7	140	21	10	96
Starches, - - - - -	—	—	97.8	850	—	—	831
Milk crackers, - - -	9.3	13.1	69.2	1,870	174	245	1,294
Cookies, - - - - -	8.3	10.8	57.6	1,120	93	121	645
Sugar, - - - - -	—	—	100.0	5,480	—	—	5,480
Canned corn, - - -	3.0	1.3	22.2	1,280	38	17	284
Potatoes (15 % refuse), - -	2.1	.1	17.9	15,440	324	15	2,764
Turnips (30 % refuse), - -	1.2	.2	8.2	1,140	14	2	93
Raisins, - - - - -	2.7	.7	71.6	1,470	40	10	1,103
Total vegetable food, - -	—	—	—	36,790	1,631	489	18,561
Total animal and vegetable food, - - - - -	—	—	—	108,070	7,033	8,122	20,499
Table and kitchen wastes (a),	16.8	25.7	52.6	1,873	315	481	985

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 56.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Mason's Family.

FOOD MATERIALS.				NUTRIENTS.			Potential Energy.
				Protein.	Fat.	Carbo- hydrates.	
				Grams.*	Grams.	Grams.	Calories.
<i>For Family, 28 Days.</i>							
Food purchased, -	Animal, -	-	-	5,402	7,633	1,938	101,080
	Vegetable, -	-	-	1,631	489	18,561	87,335
	Total, -	-	-	7,033	8,122	20,499	188,415
Waste, - - -	Animal, -	-	-	228	455	—	5,165
	Vegetable, -	-	-	87	26	985	4,635
	Total, -	-	-	315	481	985	9,800
Food actually eaten,	Animal, -	-	-	5,174	7,178	1,938	95,915
	Vegetable, -	-	-	1,544	463	17,576	82,700
	Total, -	-	-	6,718	7,641	19,514	178,615
<i>Per Man, Per Day.</i>							
Food purchased, -	Animal, -	-	-	96	136	35	1,805
	Vegetable, -	-	-	29	9	331	1,560
	Total, -	-	-	125	145	366	3,365
Waste, - - -	Animal, -	-	-	4	8	—	90
	Vegetable, -	-	-	2	—	18	85
	Total, -	-	-	6	8	18	175
Food actually eaten,	Animal, -	-	-	92	128	35	1,715
	Vegetable, -	-	-	27	9	313	1,475
	Total, -	-	-	119	137	348	3,190
<i>Percentages of Total Food Purchased.</i>							
Food purchased, -	Animal, -	-	-	76.8	94.0	9.5	53.6
	Vegetable, -	-	-	23.2	6.0	90.5	46.4
	Total, -	-	-	100.0	100.0	100.0	100.0
Waste, - - -	Animal, -	-	-	3.2	5.6	—	2.7
	Vegetable, -	-	-	1.2	.3	4.8	2.5
	Total, -	-	-	4.4	5.9	4.8	5.2
Food actually eaten,	Animal, -	-	-	73.6	88.4	9.5	50.9
	Vegetable, -	-	-	22.0	5.7	85.7	43.9
	Total, -	-	-	95.6	94.1	95.2	94.8

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A CARPENTER'S FAMILY.

The study began April 29, 1893, and continued 28 days. The family (the same as in No. 8*) was as follows:—

Man (carpenter) about 35 years old, at work.

Woman of about same age (assumed = .8 of one man).

Boy about 11 years old (assumed = .7 of one man).

The meals taken were equivalent to 210 meals, or 70 days for one man.

TABLE 57.

Food Materials and Table and Kitchen Wastes in Dietary of a Carpenter's Family during Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.	%	%	%	Grams.*	Grams.	Grams.	Grams.
<i>Beef.</i>							
Sirloin, - - -	15.5	17.4	—	5,760	893	1,002	—
Cooked and canned, -	26.7	17.1	—	2,440	652	417	—
Corned rump, - - -	16.7	8.6	—	1,390	232	120	—
Rump, - - -	13.7	31.1	—	1,980	271	616	—
Liver, - - -	20.1	5.4	3.5	1,460	294	79	51
Dried beef, - - -	28.8	4.4	1.4	60	17	3	1
Total, - - -	—	—	—	13,090	2,359	2,237	52
<i>Pork.</i>							
Salted, - - -	.9	82.8	—	570	5	472	—
Ham, - - -	14.8	34.6	—	2,880	426	996	—
Lard, - - -	—	99.8	—	1,560	—	1,557	—
Total, - - -	—	—	—	5,010	431	3,025	—
<i>Fish, Etc.</i>							
Salt cod, - - -	10.6	.2	—	1,160	123	2	—
Canned salmon, - -	20.9	13.9	—	1,400	293	195	—
Canned clams, - -	10.4	.8	3.0	470	49	4	14
Total, - - -	—	—	—	3,030	465	201	14
<i>Dairy Products, Etc.</i>							
Whole milk (a), - -	3.6	3.8	3.2	15,600	562	593	499
Skim milk (a), - -	2.4	.1	5.1	31,070	745	31	1,585
Butter, - - -	—	85.0	—	1,570	—	1,335	—
Cheese, - - -	28.0	35.3	2.1	160	45	57	3
Total, - - -	—	—	—	48,400	1,352	2,016	2,087
Eggs, - - -	12.6	10.5	—	3,390	427	356	—
Total animal food,	—	—	—	72,920	5,034	7,835	2,153

* Report of this Station for 1892, page 158.

† 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 57.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
VEGETABLE FOOD.	%	%	%	Grams.*	Grams.	Grams.	Grams.
Flour (<i>a</i>), - - -	11.0	1.1	74.9	2,180	240	24	1,633
Rex wheat (<i>a</i>), - - -	11.4	2.1	74.5	140	16	3	104
Starch, etc., - - -	—	—	97.8	110	—	—	108
Wheat bread, - - -	9.1	1.6	56.0	17,410	1,584	279	9,750
Cake, - - - - -	8.3	10.8	57.8	4,090	340	442	2,364
Crackers, - - - -	9.3	13.1	69.2	1,130	105	148	782
Sugar, - - - - -	—	—	100.0	980	—	—	980
Potatoes (15 % refuse), -	2.1	.1	17.9	33,110	695	33	5,927
Spinach, - - - -	2.1	.5	3.1	1,010	21	5	31
Canned squash, - - -	1.1	.5	9.9	1,020	11	5	101
Canned peas, - - -	4.2	.4	11.4	770	32	3	88
Dried apricots, - - -	2.3	.5	66.5	230	5	1	153
Total vegetable food,	—	—	—	62,180	3,049	943	22,021
Total animal and vegetable food, - - -	—	—	—	135,100	8,083	8,777	24,174
Table and kitchen wastes (<i>a</i>), - - -	24.7	18.1	51.6	1,319	326	239	681

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 58.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Carpenter's Family.

FOOD MATERIALS.				NUTRIENTS.			Potential Energy.
				Protein.	Fat.	Carbo- hydrates.	
<i>For Family, 28 Days.</i>				Grams.*	Grams.	Grams.	Calories.
Food purchased, -	{	Animal, - - -	-	5,034	7,835	2,153	102,330
		Vegetable, - - -	-	3,049	942	22,021	111,550
Waste, - - -	{	Total, - - -	-	8,083	8,777	24,174	213,880
		Animal, - - -	-	232	210	—	2,900
		Vegetable, - - -	-	94	29	681	3,450
Food actually eaten,	{	Total, - - -	-	326	239	681	6,350
		Animal, - - -	-	4,802	7,625	2,153	99,430
		Vegetable, - - -	-	2,955	913	21,340	108,100
		Total, - - -	-	7,757	8,538	23,493	207,530
<i>Per Man, Per Day.</i>							
Food purchased, -	{	Animal, - - -	-	72	112	31	1,460
		Vegetable, - - -	-	43	13	315	1,595
Waste, - - -	{	Total, - - -	-	115	125	346	3,055
		Animal, - - -	-	3	3	—	40
		Vegetable, - - -	-	1	—	10	50
Food actually eaten,	{	Total, - - -	-	4	3	10	90
		Animal, - - -	-	69	109	31	1,420
		Vegetable, - - -	-	42	13	305	1,545
		Total, - - -	-	111	122	336	2,965
<i>Percentages of Total Food Purchased.</i>							
Food purchased, -	{	Animal, - - -	-	62.3	89.3	8.8	47.8
		Vegetable, - - -	-	37.7	10.7	91.2	52.2
Waste, - - -	{	Total, - - -	-	100.0	100.0	100.0	100.0
		Animal, - - -	-	3.6	2.4	—	1.4
		Vegetable, - - -	-	1.5	.3	1.4	1.6
Food actually eaten,	{	Total, - - -	-	5.1	2.7	1.4	3.0
		Animal, - - -	-	58.7	86.9	8.8	46.4
		Vegetable, - - -	-	36.2	10.4	89.8	50.6
		Total, - - -	-	94.9	97.3	98.6	97.0

*100 grams=3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF A COLLEGE CLUB.

The study began April 13, 1893, and continued 28 days.

The family was as follows:—

Twenty-seven students in college (2,154 meals).

Two women at moderate exercise (each assumed = .8 of one man).

Two servants (each assumed = .8 of one man).

The meals taken were equivalent to 2,421 meals, or 807 days for one man.

TABLE 59.

Food Materials and Table and Kitchen Wastes in Dietary of a College Club During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.	%	%	%	*Grams.	Grams.	Grams.	Grams.
<i>Beef.</i>							
Sirloin (<i>a</i>), - - -	16.9	15.9	—	37,930	6,410	6,031	—
Ribs (<i>a</i>), - - -	14.6	25.3	—	21,830	3,187	5,523	—
Shoulder clod, - - -	17.0	13.7	—	14,000	2,380	1,918	—
Shoulder clod free from bone (<i>a</i>), - - -	20.9	6.4	—	23,130	4,834	1,480	—
Rump, - - -	13.7	31.1	—	7,120	975	2,214	—
Round steak (<i>a</i>), - - -	17.4	16.6	—	18,230	3,172	3,026	—
Corned rump (<i>a</i>), - - -	16.7	12.1	—	13,380	2,234	1,619	—
Canned, corned, - - -	26.7	17.1	—	1,810	483	310	—
Liver, - - -	20.1	5.4	3.5	1,470	295	79	51
Dried beef, - - -	28.8	4.4	1.4	880	253	39	12
Total, - - -	—	—	—	139,780	24,223	22,239	63
<i>Veal.</i>							
Shoulder (<i>a</i>), - - -	14.8	11.9	—	11,310	1,674	1,346	—
Loin (<i>a</i>), - - -	14.6	15.5	—	13,610	1,987	2,110	—
Cutlets (<i>a</i>), - - -	20.2	10.1	—	9,580	1,935	968	—
Total, - - -	—	—	—	34,500	5,596	4,424	—
<i>Mutton.</i>							
Chops (<i>a</i>), - - -	13.7	28.0	—	12,250	1,678	3,430	—
Leg (<i>a</i>), - - -	15.5	19.3	—	15,710	2,435	3,032	—
Loin (<i>a</i>), - - -	12.6	29.5	—	4,280	539	1,263	—
Total, - - -	—	—	—	32,240	4,652	7,725	—
<i>Pork.</i>							
Ham, - - -	14.8	34.6	—	17,580	2,602	6,083	—
Salt, - - -	.9	82.8	—	850	8	704	—
Sausage (<i>a</i>), - - -	12.1	41.6	.9	8,700	1,053	3,619	78
Chops, - - -	14.1	25.3	—	3,520	496	891	—
Lard (<i>a</i>), - - -	—	99.8	—	30,130	—	30,070	—
Total, - - -	—	—	—	60,780	4,159	41,367	78
Fowl (<i>a</i>), - - -	11.2	7.2	—	8,590	962	618	—
<i>Fish, etc.</i>							
Oysters, - - -	6.3	1.6	4.0	4,760	300	76	190
Haddock, - - -	8.2	.2	—	3,300	271	7	—
Shad, - - -	9.2	4.8	—	3,010	277	144	—
Shad roe, - - -	20.9	3.8	2.6	540	113	21	14
Salt cod, - - -	10.6	.2	—	540	57	1	—
Canned salmon (<i>a</i>), - - -	23.4	8.4	—	9,640	2,256	810	—
Total, - - -	—	—	—	21,790	3,274	1,059	204
<i>Dairy Products, etc.</i>							
Milk (<i>a</i>), - - -	3.4	4.6	4.7	371,260	12,623	17,078	17,449
Butter (<i>a</i>), - - -	—	8.9	—	47,540	—	42,311	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 59.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
	%	%	%	*Grams.	Grams.	Grams.	Grams.
Cheese, - - -	28.0	35.3	2.1	480	134	169	10
Total, - - -	—	—	—	419,280	12,757	59,558	17,459
Eggs, - - -	12.6	10.5	—	37,310	4,701	3,918	—
Total animal food, VEGETABLE FOOD.	—	—	—	754,270	60,324	140,908	17,804
Bread flour (a), -	12.3	.7	74.6	117,230	14,419	821	87,454
Pastry flour (a), -	10.1	.9	75.7	44,450	4,489	400	33,648
Corn meal, - - -	9.2	3.8	70.6	2,470	227	94	1,744
Graham flour, -	11.7	1.7	71.7	8,020	938	136	5,750
Oat meal (a), - -	13.4	6.7	70.2	10,750	1,441	720	7,547
Bread, - - -	9.1	1.6	56.0	1,360	124	22	762
Ceraline (a), - -	9.4	1.0	78.6	3,010	283	30	2,366
Wheatlet (a), - -	12.3	1.4	75.0	3,030	373	42	2,273
Rex wheat (a), -	11.4	2.1	74.5	3,630	414	76	2,704
Hominy, - - -	8.3	.4	77.4	2,440	203	10	1,889
Rice, - - -	7.4	.4	79.4	1,760	130	7	1,397
Starch, - - -	—	—	97.8	3,660	—	—	3,579
Crackers, - - -	9.3	13.1	69.2	5,670	527	743	3,924
Nonesuch mince meat (a)	4.0	2.2	67.4	2,610	104	57	1,759
Sugar, - - -	—	—	100.0	70,960	—	—	70,960
Molasses, - - -	—	—	72.0	6,410	—	—	4,615
Dried beans (a), -	21.4	1.9	57.3	3,630	777	69	2,080
Onions (10 % refuse), -	1.4	.3	10.1	2,140	30	6	216
Cabbage (edible), -	1.5	.2	4.6	1,810	27	4	83
Potatoes (30 % refuse), -	2.1	.1	17.9	166,240	3,491	166	29,757
Oranges and lemons, -	1.0	.9	8.3	34,710	347	312	2,881
Bananas (edible), -	1.4	1.4	29.8	13,580	190	190	4,047
Pine apple (edible), -	.4	.3	9.7	4,420	18	13	429
Evaporated apples, etc., -	1.3	.8	68.3	4,650	60	37	3,176
Raisins, - - -	2.7	.7	71.6	2,670	72	19	1,912
Canned raspberries, cher- ries, peaches, etc., -	1.1	.8	11.4	27,950	307	224	3,186
Canned asparagus, -	1.8	.2	3.3	3,970	71	8	131
Canned corn (a), - -	3.0	1.2	21.9	6,970	209	84	1,526
Canned tomatoes, -	1.0	.2	3.3	11,030	110	22	364
Canned squash (a), -	1.1	.5	9.9	2,440	27	12	242
Canned string beans, -	4.1	.5	13.5	7,980	327	40	1,077
Lima beans (a), - -	4.5	.5	17.0	5,790	261	29	984
Canned peas (a), - -	4.1	.5	11.5	12,220	501	61	1,405
Total vegetable food, -	—	—	—	599,660	39,497	4,454	285,867
Total animal and vege- table food purchased, Table & Kitchen Wastes (a)	—	—	—	1,353,930	90,821	145,362	303,671
No. 387, - - -	23.6	24.2	48.0	6,516	1,538	1,577	3,128
No. 391, - - -	25.8	32.0	37.3	7,543	1,946	2,414	2,814
No. 394, - - -	23.5	32.2	40.2	8,206	1,928	2,642	3,299
No. 401, - - -	25.0	30.3	40.2	6,912	1,728	2,094	2,779
No. 404, - - -	29.1	29.9	37.1	7,873	2,291	2,354	2,921
No. 408, - - -	26.5	34.0	36.2	8,185	2,169	2,783	2,963
No. 410, - - -	24.7	33.1	37.6	7,541	1,863	2,496	2,835
No. 411, - - -	23.7	36.0	36.3	9,994	2,369	3,598	3,628
Fat, - - -	—	—	—	12,080	—	12,080	—
Total, - - -	—	—	—	74,850	15,832	32,038	24,367

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 60.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a College Club.

FOOD MATERIALS.		NUTRIENTS.			Potential Energy.
		Protein.	Fat.	Carbo- hydrates.	
		Grams.*	Grams.	Grams.	Calories.
Food purchased,	Animal, -	60,324	140,908	17,804	1,630,770
	Vegetable, -	30,497	4,454	285,867	1,338,515
	Total, -	90,821	145,362	303,671	2,969,285
Waste, - - -	Animal, -	13,232	31,658	—	348,670
	Vegetable, -	2,600	380	24,367	114,100
	Total, -	15,832	32,038	24,367	462,770
Food actually eaten,	Animal, -	47,092	109,250	17,804	1,282,100
	Vegetable, -	27,897	4,074	261,500	1,224,415
	Total, -	74,989	113,324	279,304	2,506,515
<i>Per Man, Per Day.</i>					
Food purchased,	Animal, -	75	174	22	2,020
	Vegetable, -	38	6	354	1,660
	Total, -	113	180	376	3,680
Waste, - - -	Animal, -	16	39	—	430
	Vegetable, -	3	—	30	140
	Total, -	19	39	30	570
Food actually eaten,	Animal, -	57	135	22	1,590
	Vegetable, -	35	6	321	1,520
	Total, -	92	141	343	3,110
<i>Percentages of Total Food Purchased.</i>					
Food purchased, -	Animal, -	66.4	96.9	5.9	54.9
	Vegetable, -	33.6	3.1	94.1	45.1
	Total, -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, -	14.6	21.8	—	11.7
	Vegetable, -	2.9	.3	8.0	3.8
	Total, -	17.5	22.1	8.0	15.5
Food actually eaten,	Animal, -	51.8	75.1	5.9	43.2
	Vegetable, -	30.7	2.8	86.1	41.3
	Total, -	82.5	77.9	92.0	84.5

*100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

DIETARY OF THE STATION AGRICULTURIST'S FAMILY IN SUMMER.

The study began July 7, 1893 and continued 31 days.

The family was the same as in the previous dietary, (page 176) except that the servant was away and a child 1 year old was included in the dietary.

The meals taken were equivalent to 171 meals, or 57 days for one man.

TABLE 61.

Food Materials and Table and Kitchen Wastes in Dietary of the Station Agriculturist's Family During Thirty Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo-hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOOD.	%	%	%	Grams.*	Grams.	Grams.	Grams.
<i>Beef.</i>							
Rib, - - -	12.2	27.9	—	4,220	515	1,177	—
Shin, - - -	13.6	1.4	—	680	92	10	—
Round steak, - - -	18.0	12.3	—	90	16	11	—
Sirloin, - - -	15.0	16.4	—	450	68	74	—
Shoulder, - - -	17.0	13.7	—	1,270	216	174	—
Canned tongue, - - -	26.7	17.1	—	680	182	116	—
Tripe, - - -	13.9	1.8	—	590	82	11	—
Total, - - -	—	—	—	7,980	1,171	1,573	—
<i>Veal.</i>							
Steak, - - -	20.2	10.1	—	1,040	210	105	—
Loin, - - -	14.6	15.5	—	820	120	127	—
Liver, - - -	20.1	5.4	3.5	1,410	283	76	49
Heart, - - -	16.3	26.2	—	320	52	84	—
Tongue, - - -	17.4	18.0	—	270	47	49	—
Total, - - -	—	—	—	3,860	712	441	49
<i>Lamb.</i>							
Fore quarter, - - -	18.1	25.8	—	1,810	328	467	—
<i>Pork.</i>							
Ham, - - -	16.7	39.1	—	320	53	125	—
Chops, - - -	14.1	25.3	—	320	45	81	—
Pork, salted, - - -	.9	82.8	—	680	6	563	—
Lard, - - -	—	99.8	—	180	—	180	—
Total, - - -	—	—	—	1,500	104	949	—
<i>Poultry.</i>							
Chicken, - - -	15.1	1.2	—	1,180	178	14	—

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 gram

TABLE 61.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
	%	%	%	Grams.*	Grams.	Grams.	Grams.
<i>Fish, Etc.</i>							
Blue fish, - - -	9.8	.6	—	910	89	5	—
Sword fish, - - -	15.1	4.4	—	320	48	14	—
Weak fish, - - -	8.4	1.1	—	820	69	9	—
Total, - - -	—	—	—	2,050	206	28	—
<i>Dairy Products.</i>							
Milk, - - -	3.6	4.0	4.7	44,720	1,610	1,789	2,102
Cream, - - -	2.5	18.8	4.1	500	13	94	20
Butter, - - -	—	85.0	—	2,590	—	2,202	—
Cheese, - - -	28.0	35.3	2.1	540	151	191	11
Total, - - -	—	—	—	48,350	1,774	4,276	2,133
Eggs, - - -	12.6	10.5	—	3,130	394	329	—
<i>Vegetable Foods.</i>							
Flour (a), - - -	13.1	.9	73.2	10,620	1,391	96	7,774
Corn meal, - - -	9.2	3.8	70.6	270	25	10	191
Oat meal, - - -	14.7	7.1	68.4	1,680	247	119	1,149
Wheat, - - -	11.9	1.7	74.8	1,500	179	26	1,122
Rice and macaroni, -	7.4	.4	79.4	770	57	3	611
Sugar, - - -	—	—	100.0	8,210	—	—	8,210
Molasses, - - -	—	—	72.0	540	—	—	389
Beets (edible), - - -	1.1	.1	4.5	680	7	1	31
Onions (edible), - - -	1.4	.3	10.1	1,320	18	4	133
Peas (edible), - - -	4.4	.5	16.1	2,540	112	13	409
String beans (edible), -	2.2	.4	9.5	540	12	2	51
Cauliflower (edible), -	1.6	.8	5.0	770	12	6	39
Dried beans, - - -	20.7	1.8	60.4	730	151	13	441
Squash (edible), - - -	.9	.2	10.1	1,320	12	3	133
Potatoes (15 % refuse), -	2.1	.1	17.9	13,690	287	14	2,451
Lettuce (edible), - - -	1.6	.5	3.7	230	4	1	9
Cucumber (edible), - -	.8	.2	2.5	410	3	1	10
Green corn (edible), - -	2.8	1.1	14.2	540	15	6	77
Water melon (pulp), - -	.9	.7	6.2	6,940	62	49	430
Musk melon, - - -	1.4	.2	20.5	450	6	1	92
Strawberries and rasp- berries, - - -	1.0	.7	6.9	3,860	39	27	266
Whortleberries, - - -	.7	3.0	13.5	770	5	23	104
Bananas (pulp), - - -	1.4	1.4	29.8	1,000	14	14	298
Tomato (pulp), - - -	.8	.4	2.5	1,770	14	7	44
Apple (pulp), - - -	.3	.4	15.9	2,770	8	11	440
Total, - - -	—	—	—	63,920	2,680	450	24,904
Total animal and vege- table foods purchased,	—	—	—	133,780	7,547	8,527	27,086
Table & kitchen wastes, a	33.4	39.4	23.4	799	267	315	187

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 62.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of an Agriculturist's Family.

FOOD MATERIALS.				NUTRIENTS.			Potential Energy.
				Protein.	Fats.	Carbo- hydrates.	
				Grams*	Grams.	Grams.	Calories.
Food purchased, -	Animal, -	-	-	4,867	8,077	2,182	104,015
	Vegetable, -	-	-	2,680	450	24,904	117,280
				7,547	8,527	27,086	221,295
Waste, - - -	Animal, -	-	-	247	312	—	3,915
	Vegetable, -	-	-	20	3	187	875
				267	315	187	4,790
Food actually eaten,	Animal, -	-	-	4,620	7,765	2,182	100,100
	Vegetable, -	-	-	2,660	447	24,717	116,405
				7,280	8,212	26,899	216,505
<i>Per Man, Per Day.</i>							
Food purchased, -	Animal, -	-	-	86	142	38	1,825
	Vegetable, -	-	-	47	8	437	2,060
				133	150	475	3,885
Waste, - - -	Animal, -	-	-	4	5	—	70
	Vegetable, -	-	-	—	—	3	15
				4	5	3	85
Food actually eaten,	Animal, -	-	-	82	137	38	1,755
	Vegetable, -	-	-	47	8	434	2,045
				129	145	472	3,800
<i>Percentages of Total Food Purchased.</i>							
Food purchased, -	Animal, -	-	-	64.5	94.7	8.1	47.0
	Vegetable, -	-	-	35.5	5.3	91.9	53.0
				100.0	100.0	100.0	100.0
Waste, - - -	Animal, -	-	-	3.3	3.7	—	1.8
	Vegetable, -	-	-	.3	—	.7	.4
				3.6	3.7	0.7	2.2
Food actually eaten,	Animal, -	-	-	61.2	91.0	8.1	45.2
	Vegetable, -	-	-	35.2	5.3	91.2	52.6
				96.4	96.3	99.3	97.8

* 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

TABLE 63.

Summary of Results of Dietary Studies made by Station. Food per Man, per Day.

DIETARIES.		NUTRIENTS.			Potential Energy.
		Protein.	Fat.	Carbo- hydrates.	
		Grams†	Grams.	Grams.	Calories
1. <i>Dietary of a Boarding House.*</i>					
Food,	{ Purchased, - - - - -	126	188	426	4,010
	{ Waste, - - - - -	23	36	25	520
	{ Eaten, - - - - -	103	152	401	3,490
2. <i>Dietary of a Chemist's Family.*</i>					
Food purchased, † - - - - -		118	103	430	3,210
3. <i>Dietary of a Jeweler's Family.‡</i>					
Food,	{ Purchased, - - - - -	91	126	483	3,530
	{ Waste, - - - - -	8	9	5	140
	{ Eaten, - - - - -	83	117	478	3,390
4. <i>Dietary of a Blacksmith's Family.‡</i>					
Food,	{ Purchased, - - - - -	103	176	408	3,730
	{ Waste, - - - - -	3	5	7	90
	{ Eaten, - - - - -	100	171	401	3,640
5. <i>Dietary of a Machinist's Family.‡</i>					
Food,	{ Purchased, - - - - -	100	159	427	2,640
	{ Waste, - - - - -	1	3	6	60
	{ Eaten, - - - - -	99	156	421	3,580
<i>Two Dietaries of a Mason's Family.‡</i>					
6. December, 1892.					
Food,	{ Purchased, - - - - -	107	153	391	3,470
	{ Waste, - - - - -	3	5	16	120
	{ Eaten, - - - - -	104	148	375	3,350
10. May, 1893.					
Food,	{ Purchased, - - - - -	125	145	366	3,365
	{ Waste, - - - - -	6	8	18	175
	{ Eaten, - - - - -	119	137	348	3,190
<i>Average of 6 and 10.</i>					
Food,	{ Purchased, - - - - -	116	149	379	3,420
	{ Waste, - - - - -	5	6	17	150
	{ Eaten, - - - - -	111	143	362	3,270
7. <i>Dietary of a Carpenter's Family.‡</i>					
Food,	{ Purchased, - - - - -	125	152	498	3,970
	{ Waste, - - - - -	11	17	23	300
	{ Eaten, - - - - -	114	135	475	3,670

TABLE 63.—(Continued.)

DIETARIES.						NUTRIENTS.			Potential Energy.
						Protein.	Fat.	Carbo- hydrates.	
						Grams†	Grams.	Grams.	Calories
<i>Two Diaries of a Carpenter's Family. §</i>									
8. November, 1892.									
Food,	{	Purchased,	-	-	-	107	161	408	3,610
	{	Waste,	-	-	-	7	12	20	220
	{	Eaten,	-	-	-	100	149	388	3,390
11. May, 1893.									
Food,	{	Purchased,	-	-	-	115	125	346	3,055
	{	Waste,	-	-	-	4	3	10	90
	{	Eaten,	-	-	-	111	122	336	2,965
<i>Average of 8 and 11.</i>									
Food,	{	Purchased,	-	-	-	111	144	377	3,335
	{	Waste,	-	-	-	6	8	15	150
	{	Eaten,	-	-	-	105	135	362	3,185
<i>Two Diaries of Station Agriculturist's Family.</i>									
9. Winter, 1893.									
Food,	{	Purchased,	-	-	-	106	145	405	3,450
	{	Waste,	-	-	-	7	6	7	115
	{	Eaten,	-	-	-	99	139	398	3,335
13. Summer, 1893.									
Food,	{	Purchased,	-	-	-	133	150	475	3,885
	{	Waste,	-	-	-	4	5	3	85
	{	Eaten,	-	-	-	129	145	472	3,800
<i>Average of 9 and 13.</i>									
Food,	{	Purchased,	-	-	-	120	147	440	3,670
	{	Waste,	-	-	-	6	5	5	100
	{	Eaten,	-	-	-	114	142	435	3,570
12. <i>Dietary of a Students' Club.</i>									
Food,	{	Purchased,	-	-	-	113	180	376	3,680
	{	Waste,	-	-	-	19	39	30	570
	{	Eaten,	-	-	-	92	141	343	3,110
Food eaten,	{	Minimum of above,	-	-	-	83	103	336	2,965
	{	Maximum of above,	-	-	-	120	171	478	3,800
	{	Average of above,	-	-	-	105	140	405	3,395
<i>Dietary Standards for Men at Moderate Work.</i>									
Voit (German),						118	56	500	3,060
Atwater (American).						125	125	450	3,560

* Report of this Station, 1892, pages 135-162.

† 100 grams = 3.5 ounces, or .22 pounds. 1 ounce = 28.35 grams. 1 pound = 453.6 grams.

‡ There was very little waste in this dietary.

§ Report of this Station, 1891, pages 90-106.

DIETARY STUDIES IN THE UNITED STATES AND ELSEWHERE.

In the Report of this Station for 1892 considerable space was devoted to the subjects of food and dietaries. In the Report for 1892 was a short chapter on "Economy of Food." Bulletin No. 7 of the Station treated of similar subjects. The favor with which these publications have been received has been most encouraging. Among the evidences that such inquiry is coming to be regarded as most useful, is the fact that the Secretary of Agriculture has recommended to Congress an appropriation of \$10,000 for the study of the subject by the Department of Agriculture in connection with the experiment stations and otherwise, and that the Office of Experiment Stations of that Department has undertaken the compilation of results of inquiries in this country and in Europe regarding the economy of food.

In connection with this compilation, which has been placed in my charge, I have, with the aid of Drs. H. B. Gibson and C. F. Langworthy, endeavored to collate the results of the studies of dietaries made in this direction up to the present time. We have found records of the examination of 491 separate dietaries, exclusive of army rations. The most of these have been made in Europe. The earliest date back to 1851. The majority have been made during the past 15 years and by far the larger number of the most reliable ones during the past 10 years. The people whose dietaries have been studied have been of various classes, ages and occupations. A few were in professional life and were decidedly well-to-do. The most were wage workers; some of these were very poor, but the larger number were in reasonably comfortable circumstances as compared with the majority of people of like occupation in the countries where they lived.

From the 491 dietaries we have selected 338 as accurate enough to warrant their use in drawing inferences. The number of persons whose food consumption was observed in each dietary of this selected list varied from a single individual to several hundred. The time of observation in each case was from one to thirty days. This list of 338 we have divided in two classes, the first including all the studies that seem to us reasonably accurate and complete; the second including those which are less accurate; but sufficiently so to allow their results to be included in the general averages. The classification of all these dietaries by countries and by completeness of detail is summarized in the following tabular statement.

NUMBER OF DIETARIES COLLATED.

Classified by Countries and by completeness of detail.

A. Reasonably accurate and complete. B. Less accurate, but included in averages. C. Not included in averages.

	A	B	C	A+B	A+B+C
EUROPE.					
England, - - - - -	—	7	49	7	56
Scotland, Wales and Ireland, - - - - -	—	—	9	—	9
France, - - - - -	—	1	5	1	6
Belgium, - - - - -	—	—	15	—	15
Denmark and Sweden, - - - - -	15	—	—	15	15
Russia, - - - - -	4	25	—	29	29
Germany, - - - - -	54	97	35	151	186
Austria, - - - - -	—	3	—	3	3
Switzerland, - - - - -	2	—	10	2	12
Italy, - - - - -	15	—	15	15	30
Spain and Portugal, - - - - -	—	—	6	—	6
Total, Europe, - - - - -	90	133	144	223	367
ASIA.					
India, - - - - -	—	—	7	—	7
Java,* - - - - -	1	—	—	1	1
Japan, - - - - -	8	5	1	13	14
Total, Asia, - - - - -	9	5	8	14	22
CANADA.					
	—	13	—	13	13
UNITED STATES.					
Massachusetts, - - - - -	—	19	—	19	19
Connecticut, - - - - -	13	5	1	18	19
Penn., Philadelphia, - - - - -	—	25	—	25	25
Ill., Chicago, - - - - -	—	26	—	26	26
Total, United States, - - - - -	13	75	1	88	89
Total, North America, - - - - -	13	88	1	101	102
Grand Total, - - - - -	112	226	153	338	491

*Java Village, World's Fair, Chicago.

It will be observed that of the 338 dietaries of the first two classes, 101 were made in the United States and Canada, of which 38 were in New England, 25 in Philadelphia, and 26 in Chicago. All of these were observed during the past eight years, and all but those in the two cities last named were studied by the writer and his assistants at Wesleyan University in coöperation with the Massachusetts Bureau and the U. S. Department of Labor, and as part of the work of the Storrs Experiment Station.

Of the European dietaries in the selected list, only seven are from England; those were determined by Playfair some 30 years ago. Only one comes from France, 15 are from Sweden and Denmark, and 29 from Russia. From Germany are 151, of which the earliest were by Liebig and a very large number are by Voit and his followers. From Italy are 15, of which eight are by Manfredi and six by Albertoni and Novi; these 14 include some of the latest and most thoroughly studied of all. From Japan are 13, all of which have been made lately by Germans connected with the University of Tokio and by Japanese working with them. One was the dietary of Javanese in the Java village at the World's Fair; this was studied in connection with the examinations of foods made under the direction of the writer and referred to on page 14 of this Report.

My object in citing these statistics is to call attention to the fact that this kind of inquiry is to-day well under way in several parts of the world. It represents the beginning of a science, that of the comparative nutrition of mankind, the comparisons being made by race, class, occupation, income, and social condition.

This investigation of the habits of food consumption is a branch of the general science of nutrition. It represents the broad, practical, humanitarian side of that science. The facts it seeks to find out and set in order are of the greatest importance. In connection with the coördinate facts of housing, clothing, occupation, income, and expenditure, and the like, they belong to the fundamental data of the great problem of human living. They are indispensable for the right understanding of the status of the different classes and races of men and the ways of elevating them.

The other side of the science of nutrition comes more fully within the domain of chemistry, physics and physiology; it begins with the study of food and the ways it is used in the body; it culminates in the study of the laws of the conservation of matter and of energy, and their application to the living organism. An effort in this last direction is being made in the development of the respiration calorimeter to which reference was made on page 16 of this Report.

The study of food and dietaries has an intensely practical side. It comes home to every household and to every person. It is most intimately connected with our health and our strength for work, for our bodies are built up and kept in repair by our food, and food gives us power for the labor of hand and brain. It reaches

deep into the purse, for half the earnings of the wage workers of Connecticut, as of the rest of Christendom, are spent and must be spent for food.

The results of examinations of dietaries which are cited in detail in this article, represent a part of a series of observations which are being carried on year after year. Some of the practical applications were given in the two previous Annual Reports of the Station, namely those for 1891 and 1892. In an article in the latter on *The Economy of Food*, considerable space was given to the practical aspect of the subject in its bearing upon personal and household economy. It is hoped that future publications will contain still more information of practical as well as theoretical interest.

IMMEDIATE PRACTICAL APPLICATIONS. AGRICULTURAL BEARINGS OF THE SUBJECT.

In closing, I may recapitulate in a few words some of the practical bearings of the subject. Scientific research, interpreting the observations of practical life, indicates that we make a four-fold mistake in our food economy.

First, we purchase needlessly expensive kinds of food. We do this under the false impression that there is some peculiar virtue in the costlier food materials, and that economy in our diet is somehow detrimental to our dignity or our welfare. And, unfortunately, those who are most extravagant in this respect are often the ones who can least afford it.

Secondly, the food which we eat does not always contain the proper proportions of the different kinds of nutritive ingredients. We consume relatively too much of the fuel ingredients of food, such as the fats of meat and butter, the starch which makes up the larger part of the nutritive material of flour and potatoes, and sugar and sweetmeats. Conversely, we have relatively too little of the protein or flesh-forming substances, like the lean of meat and fish, and the gluten of wheat, which make muscle and sinew and which are the basis of blood, bone, and brain.

Thirdly, many people, not only the well-to-do, but those in moderate circumstances, use needless quantities of food. Part of the excess, however, is simply thrown away with the wastes of the table and kitchen; so that the injury to health, great as it may be, is doubtless much less than if all were eaten. Probably

the worst sufferers from this evil are well-to-do people of sedentary occupations—brain-workers as distinguished from hand-workers.

Finally, we are guilty of serious errors in our cooking. We waste a great deal of fuel in the preparation of our food, and even then a great deal of the food is very badly cooked. A reform in the methods of cooking is one of the economic demands of our time.

To the farmer the subject is of vital interest. The agricultural production of the United States is out of balance. Our food supply for man and beast contains an excess of the materials which serve the body for fuel, and are relatively deficient in the nitrogenous compounds which make blood, muscle, and bone. In other words, the farmer produces relatively too much starch, sugar, and other carbohydrates; too much fat and too little protein. The crops he grows are, taken together, deficient in protein, and the meat he makes is excessively fat. The one-sidedness of our food consumption is the natural result of the one-sidedness of our food production.

The remedy for the evil is in growing crops with more protein. The needed increase of protein may be obtained by use of nitrogenous manures, by breeding and importing varieties of grains and grasses richer in nitrogen than those we now cultivate, and by growing more legumes, such as clovers, alfalfa, vetch, seradella, cow peas, peas, and beans.

The legumes do not require nitrogen in manure, but do well with the less expensive mineral fertilizers. They obtain nitrogen directly from the air and convert it into protein. The farmer needs this protein for fodder; by mixing the leguminous products with poor hay, straw, and cornstalks, which lack protein, the latter can be most profitably utilized. The food thus produced for stock is what is needed to make more meat and at the same time meat which will be tender and juicy without excess of fat, and to make more milk at less cost. The nitrogen not transformed into meat or milk makes rich manure for grasses, grains, and other crops. And finally, the richer manure helps to bring larger crops and crops richer in protein.

The error which causes the one-sidedness of our agricultural production brings cumulative ill; the means for amending it will bring cumulative good.

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STATE OF CONNECTICUT.

SEVENTH ANNUAL REPORT

—OF THE—

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1894.

Printed by Order of the General Assembly.

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BOARD OF TRUSTEES

— OF THE —

STORRS AGRICULTURAL COLLEGE.

HIS EXCELLENCY O. VINCENT COFFIN.

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S. W. JOHNSON,

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J. H. HALE,

E. C. PINNEY.

The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural College. The chemical and other more abstract work is carried out at Wesleyan University, Middletown.

OFFICERS OF THE STATION.

EXECUTIVE COMMITTEE.

T. S. GOLD, West Cornwall,	}	- - -	}	<i>Of the Board of Trustees of</i>
J. M. HUBBARD, Middletown,				<i>Storrs Agricultural College.</i>
B. F. KOONS, Storrs,	-	-	-	<i>President of the College.</i>

TREASURER.

HENRY C. MILES, Milford.

STATION STAFF.

W. O. ATWATER, Middletown,	-	-	-	-	-	-	<i>Director.</i>
C. D. WOODS, Middletown,	-	-	-	-	-	-	<i>Vice-Director and Chemist.</i>
C. S. PHELPS, Storrs,	-	-	-	-	-	-	<i>Agriculturist.</i>
S. H. BUELL, Storrs,	-	-	-	-	-	-	<i>Assistant in Farm Experiment.</i>

Report of the Executive Committee.

*To His Excellency O. Vincent Coffin,
Governor of Connecticut.*

In accordance with the resolution of the General Assembly concerning the Congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly, approved March 6th, 1889, relating to the publication of Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Seventh Annual Report of that Station, namely, that for the year 1894.

The Committee refer to the accompanying report of the Treasurer for details of expenditures, and to that of the Director and his associates for the history of the work accomplished, and express their confident belief that the funds have been wisely expended and that the work is such as will result in great benefit to our agricultural interests.

Respectfully submitted,

T. S. GOLD,	} <i>Executive</i>
J. M. HUBBARD,	
B. F. KOONS.	

Committee.

Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30, 1894.

The following summary of receipts and expenditures is made out in accordance with the form recommended by the Association of American Agricultural Colleges and Experiment Stations, and approved by the United States Treasury Department. The accounts have been duly audited by the Auditors of Public Accounts of the State of Connecticut:

TABULAR STATEMENT OF RECEIPTS AND EXPENDITURES.

RECEIPTS.									
U. S. Treasury,	-	-	-	-	-	-	-	-	\$7,500 00
Sale of produce,	-	-	-	-	-	-	-	-	42 63
Analyses,	-	-	-	-	-	-	-	-	86 50
Balance from 1892-93,	-	-	-	-	-	-	-	-	3 76
									\$7,632 89
EXPENDITURES.									
Salaries,	-	-	-	-	-	-	-	-	\$4,767 89
Building,	-	-	-	-	-	-	-	-	73 30
Traveling expenses,	-	-	-	-	-	-	-	-	250 64
Executive Committee and Treasurer,	-	-	-	-	-	-	-	-	161 62
Stationery and printing,	-	-	-	-	-	-	-	-	82 18
Postage, telegraph and telephone,	-	-	-	-	-	-	-	-	169 19
Fixtures, permanent,	-	-	-	-	-	-	-	-	177 84
Fixtures, not permanent,	-	-	-	-	-	-	-	-	33 79
Office furniture,	-	-	-	-	-	-	-	-	130 90
Field experiments,	-	-	-	-	-	-	-	-	364 13
Feeding experiments,	-	-	-	-	-	-	-	-	251 49
Team,	-	-	-	-	-	-	-	-	72 67
Student and other labor,	-	-	-	-	-	-	-	-	172 80
Apparatus, immediate,	-	-	-	-	-	-	-	-	238 88
Apparatus, permanent,	-	-	-	-	-	-	-	-	68 52
Chemicals,	-	-	-	-	-	-	-	-	106 37
Fuel, light and power,	-	-	-	-	-	-	-	-	161 47
Hardware and lumber,	-	-	-	-	-	-	-	-	24 61
Freight, cartage and express,	-	-	-	-	-	-	-	-	133 88
Dietary investigations,	-	-	-	-	-	-	-	-	51 59
Bacteriological investigations,	-	-	-	-	-	-	-	-	79 76
Insurance,	-	-	-	-	-	-	-	-	36 75
Incidentals,	-	-	-	-	-	-	-	-	41 21
Balance in Treasury,	-	-	-	-	-	-	-	-	1 41
									\$7,632 89

HENRY C. MILES, *Treasurer.*

Report of the Director

FOR THE YEAR 1894.



The principal lines of inquiry prosecuted during the past year may be concisely stated as follows:

1. Meteorological observations.
2. Field experiments with fertilizers.
3. Experiments on the growth of forage plants.
4. Feeding experiments with sheep.
5. Digestion experiments with sheep.
6. Studies of rations fed to milch cows on dairy farms in Connecticut.
7. Studies of bacteria and their action in the ripening of cream.
8. Analyses of feeding stuffs.
9. Analyses of materials used for the food of man.
10. Investigations of dietaries.
11. Experiments with the bomb calorimeter.
12. Development of a respiration calorimeter.

The larger part of the work done during the year is in continuation of that described in previous reports of the Station.

For an institution with an annual income of only \$7,500 per year, which is the amount received by the Storrs Station from public sources, so wide a range of subjects of investigation might seem inexcusable. The justification is found in two facts. One is that several lines of investigation upon the food and nutrition of animals and man are more or less nearly parallel with each other and are so conducted as to form really one department of inquiry. The other is that a considerable part of the work is done with the coöperation and aid of the United States Department of Agriculture, the United States Department of Labor, and Wesleyan University.

W. O. ATWATER,

Director.

BUTTER-FAT vs. SPACE SYSTEM FOR PAYING FOR CREAM AT CREAMERIES.

BY CHAS. D. WOODS.

That the milk from different cows varies materially in its composition has been long understood. It is, however, but a few years since advocates of a deep setting system for cream claimed that when it was raised under uniform conditions, a space of cream always contained the same amount of butter-fat. When this Station undertook, in 1890, a series of feeding experiments with milch cows, a Cooley creamer was purchased and the instructions as to temperature of milk at time of setting, temperature of water, etc., were carefully followed. Analyses of the cream speedily convinced us that the method was far too inaccurate to be relied upon as a measure of the butter-fat production of cows. The range of composition of the cream may be seen from the following tabulation of a few of the results obtained.

Percentage of Butter-fat in Cooley cream from milk set under uniform conditions of temperature, etc. Each analysis represents 5 days' cream.

Cow No. 1.	Cow No. 2.	Cow No. 3.	Cow No. 4.
%	%	%	%
20.33	21.11	21.10	22.46
20.01	21.32	21.06	23.30
19.48	21.16	20.84	22.45
18.41	20.30	19.57	20.90
18.78	21.54	19.64	20.82
18.79	21.70	19.84	20.84
20.18	20.23	20.87	21.31
19.89	—	21.19	21.22
Minimum, 18.41	20.23	19.57	20.82
Maximum, 20.33	21.70	21.19	23.30
Average, 19.48	21.05	20.51	21.66

The time during which the above samples were taken was about two months. The analyses were made by the gravimetric method. Each of the percentages in the table represents the result of the analyses of five days' cream. It will be observed that there is a range of from 1.5 to 2.5 per cent. in the butter-fat of the cream of the same cow, that of Cow No. 1, for instance, varies from 18.4 to 20.3 per cent. There is also a range of 5 per cent. in the butter-fat of the cream of different cows; from 18.4 in cream from the milk of Cow No. 1 to 23.3 in that of Cow No. 4.

Since these trials we have no doubt as to the unfairness of the space system of paying for cream. If such wide variations in the composition of the cream occurred when every precaution was taken to insure uniformity of conditions, it is evident that the differences would be greater under the usual management of creameries by different patrons. In addition it is possible for dishonest patrons to "manipulate" the cream so as to increase the number of space readings. Moreover, during the winter time many creameries collect the cream only two or three times per week and allow their patrons to draw their own cream and report the number of spaces to the gatherer. The temptations to increase the returns by drawing a few spaces of skim milk with the cream and reporting it all as cream, are frequently too great for human nature to resist.

During the years 1890 to 1893 occasional analyses were made of cream from different creameries and, as was to be expected, a great range in composition of the cream was found. Early in 1894, a creamery in the State asked the assistance of the Station in examining the cream collected on one of its routes. At this time the cream on this route was gathered three times per week, Mondays, Wednesdays and Fridays. For the Monday gathering the patrons were allowed to draw the cream of Friday's and Saturday's setting and report the number of spaces to the gatherer. The Sunday's cream was drawn by the gatherer on Monday morning.

One Monday morning, without previous notice to the patrons, the Friday's and Saturday's cream which had been drawn by the patrons was weighed and samples were taken for analyses. The number of spaces of cream were taken as reported by the patrons. The table on the following page contains the results of the analyses of the cream thus collected.

Comparison of the Space and Butter-fat Systems of Valuation for one gathering of cream on a suspected route. The cream was drawn by the patron, and "set out" for the gatherer. The number of spaces are as reported by the patrons.

Patron's Number.	Spaces of Cream.	Pounds of Cream.	Per Cent. Fat in Cream.	Pounds of Butter-fat.*	Spaces to 1 pound Butter-fat.*	Cost at 3 cts. per Space.	Value at 23.13 cts. per pound for Butter-fat.*	Overpaid. + Underpaid. -	Value per Space when 3 cts. is the average.
51	55	32	15.6	5.0	11.0	\$1.65	\$.16	+.49	2.1c.
52	42	25	17.1	4.3	9.8	1.26	.99	+.27	2.4
53	42	27	13.3	3.6	11.6	1.26	.83	+.43	2.0
54	45	31	16.4	5.1	8.8	1.35	1.18	+.17	2.6
55	40	26	17.0	4.4	9.0	1.20	1.02	+.18	2.6
56	40	27	11.0	3.0	13.3	1.20	.69	+.51	1.7
57	19	11	14.4	1.6	11.9	.57	.37	+.20	2.0
58	15	12	17.1	2.1	7.1	.45	.49	-.04	3.3
59	30	19	16.5	3.1	9.7	.90	.72	+.18	2.4
60	191	119	20.0	23.8	8.0	5.73	5.50	+.23	2.9
61	88	54	19.8	10.7	8.2	2.64	2.47	+.17	2.8
62	60	56	17.0	9.5	6.3	1.80	2.20	-.40	3.7
63	17	9	24.0	2.2	7.7	.51	.51	—	3.0
64	63	41	18.7	7.7	8.2	1.89	1.78	+.11	2.8
65	63	44	19.0	8.4	7.5	1.89	1.94	-.05	3.1
66	45	53	16.8	8.9	5.1	1.35	2.06	-.71	4.6
67	92	74	20.5	15.2	6.1	2.76	3.51	-.75	3.8
68	78	46	19.3	8.9	8.8	2.34	2.06	+.28	2.6
69	40	31	17.7	5.5	7.3	1.20	1.27	-.07	3.2
70	55	36	18.7	6.7	8.2	1.65	1.55	+.10	2.8
71	94	50	17.7	8.9	10.6	2.82	2.06	+.76	2.2
72	84	53	20.6	10.9	7.7	2.52	2.52	—	3.0
73	38	26	17.0	4.4	8.6	1.14	1.02	+.12	2.7
74	23	13	18.2	2.4	9.6	.69	.55	+.14	2.4
Total,	1359	915	—	166.3	8.2	—	—	—	—

* One pound of butter-fat is nearly equal to 1.18 lbs. of average butter.

During the month the creamery gathered 62,702 spaces of cream, for which it paid at the rate of 3c. per space. The output for the month was 9,573 pounds of butter. Hence on the average it required 6.55 spaces for each pound of butter. Assuming the butter to be of average composition and to have 85 per cent. of butter-fat, it required on the average 7.71 spaces of cream for each pound of butter-fat. At 3 cents per space the butter-fat would cost on the average 23.13 cents per pound.

That many of the patrons on this route were taking advantage of the way in which the cream was gathered is apparent. It will be observed that it required on the whole route 8.2 spaces of the cream which the patrons drew themselves to make a pound of

butter-fat, while the average for the whole creamery for the month was 7.7 spaces. The number of spaces ranged from 5.1 to 13.3 for one pound of butter-fat. In the case of patron 66, where only 5.1 spaces of cream were required for a pound of butter-fat, it will be noticed that the 45 spaces of cream which were reported as being furnished, weighed 53 pounds, or nearly 1.2 pounds per space instead of the two-thirds of a pound which a space of cream usually weighs. Evidently there was some mistake in the number of spaces which were returned, and as the percentage of butter-fat is rather low, it may be that the patron was intending to return a higher number of spaces, but changed his mind when he saw that samples were being taken. It will also be observed that numbers 62 and 67 have large weights of cream as compared with the number of spaces reported.

The percentages of butter-fat in the cream of this route ranged from 11 to 24 per cent. The average for the route was 16.9 per cent. butter-fat. The fourth column from the last in the table on page 9 shows what was actually paid the patrons for the cream which they drew themselves. The next column gives its value as based upon what the butter-fat cost the creamery on the average for the month, and the next to the last column shows how much each patron was overpaid or underpaid for this lot of cream. With the exception of numbers 62, 66 and 67 above noted, nearly every patron received the full value or more. Probably in these instances, and perhaps in some others, there were mistakes made by the patrons in returning the number of spaces of cream. The last column shows the value per space of the cream which the patrons furnished when the entire cream of the month was paid for at the rate of 3 cents per space. It will be observed that the range is from 1.7 cents per space to 4.6; the three who were the most underpaid per space being Nos. 62, 66 and 67 above noted.

Naturally these figures made considerable impression upon the managers of the creamery, and they desired further tests of the cream furnished them. As no complete observations had been made upon the comparisons of the butter-fat and space systems of paying for cream for long periods of time, such comparisons were made by the Station in this creamery during the entire month of April, 1894. The actual payments of the creamery were made for this month, as for previous ones, by the space system. The table which follows gives the record of the creamery for the month, by both the butter-fat and the space systems. The arrangement is the same as in the preceding table.

Comparison of the Space and Butter-fat Systems of Valuation in a Creamery for the Month of April, 1894.

Patron's Number.	Spaces of Cream.	Pounds of Cream.	Per Cent. Fat in Cream.	Pounds of Butter-fat.*	Spaces to 1 pound Butter-fat.*	Cost at 3 cts. per Space.	Value at 22.92 cts. per pound for Butter-fat.*	Overpaid. + Underpaid. —	Value per Space when 3 cts. is the average.
101	444	285	20.4	58.1	7.6	\$13.32	\$13.32	\$ —	3.00.
102	1112	726	20.4	148.1	7.5	33.36	33.94	— .58	3.1
103	1593	1045	21.4	223.6	7.1	47.79	51.25	— 3.46	3.2
104	887	578	19.7	113.9	7.8	26.61	26.11	+ .50	2.9
105	1545	1026	21.0	215.5	7.2	46.35	49.39	— 3.04	3.2
106	1473	961	20.3	194.9	7.6	44.19	44.67	— .48	3.0
107	1966	1264	19.4	245.2	8.0	58.98	56.20	+ 2.78	2.9
108	827	563	20.5	115.4	7.2	24.81	26.45	— 1.64	3.2
109	620	452	19.0	85.9	7.2	18.60	19.69	— 1.09	3.2
110	882	599	18.8	112.6	7.8	26.46	25.81	+ .65	2.9
111	309	209	19.3	40.3	7.7	9.27	9.24	+ .03	3.0
112	975	660	17.5	115.5	8.4	29.25	26.47	+ 2.78	2.7
113	337	241	18.0	43.4	7.8	10.11	9.95	+ .16	3.0
114	613	441	16.5	72.8	8.4	18.39	16.69	+ 1.70	2.7
115	604	388	17.1	66.3	9.1	18.12	15.20	+ 2.92	2.5
116	661	445	16.8	74.8	8.8	19.83	17.14	+ 2.69	2.6
117	280	195	17.1	33.3	8.4	8.40	7.63	+ .77	2.7
118	496	320	19.2	61.4	8.1	14.88	14.07	+ .81	2.8
119	283	190	17.7	33.6	8.4	8.49	7.70	+ .79	2.8
120	94	67	16.3	10.8	8.7	2.82	2.48	+ .34	2.6
121	621	411	16.6	68.2	9.1	18.63	15.63	+ 3.00	2.5
122	498	328	21.4	70.5	7.1	14.94	16.16	— 1.22	3.2
123	729	525	18.5	97.6	7.5	21.87	22.37	— .50	3.1
124	410	292	19.4	56.6	7.2	12.30	12.97	— .67	3.2
125	500	352	20.3	71.5	7.0	15.00	16.39	— 1.39	3.3
126	990	687	19.8	136.1	7.3	29.70	31.19	— 1.49	3.2
127	1704	1201	21.1	253.0	6.7	51.12	57.99	— 6.87	3.4
128	1136	775	19.9	154.1	7.4	34.08	35.31	— 1.23	3.1
129	689	491	20.0	98.2	7.0	20.67	22.51	— 1.84	3.3
130	248	167	19.2	31.9	7.8	7.44	7.31	+ .13	3.0
131	552	378	21.7	81.9	6.7	16.56	18.77	— 2.21	3.4
132	774	497	17.6	87.5	8.8	23.22	20.06	+ 3.16	2.6
133	357	223	20.4	45.5	7.8	10.71	10.43	+ .28	2.9
134	551	349	20.8	72.6	7.6	16.53	16.64	— .11	3.0
135	2165	1385	21.2	293.6	7.4	64.95	67.29	— 2.34	3.1
136	689	414	19.9	82.4	8.4	20.67	18.89	+ 1.78	2.7
137	567	353	16.8	59.3	9.6	17.01	13.59	+ 3.42	2.4
138	1369	890	20.2	179.7	7.6	41.07	41.19	— .12	3.0
139	454	316	17.0	53.7	8.5	13.62	12.31	+ 1.31	2.7
140	493	337	19.7	66.4	7.4	14.79	15.22	— .43	3.1
141	739	561	17.7	99.3	7.4	22.17	22.76	— .59	3.0
142	290	196	19.2	37.5	7.7	8.70	8.60	+ .10	3.0
143	959	620	20.8	129.0	7.4	28.77	29.57	— .80	3.1
144	575	368	20.1	73.9	7.8	17.25	16.94	+ .31	2.9
145	1196	760	21.2	161.0	7.4	35.88	36.90	— 1.02	3.1
146	477	287	18.0	51.7	9.2	14.31	11.85	+ 2.46	2.5
147	1201	790	18.3	144.6	8.3	36.03	33.14	+ 2.89	2.8
148	740	492	19.4	95.5	7.7	22.20	21.89	+ .31	3.0
149	472	307	20.2	62.0	7.6	14.16	14.21	— .05	3.0

Comparison of the Space and Butter-fat Systems of Variation in a Creamery for the Month of April, 1894.—Concluded.

Patron's Number.	Spaces of Cream.	Pounds of Cream.	Per Cent. Fat in Cream.	Pounds of Butter-fat.*	Spaces to 1 pound Butter-fat.*	Cost at 3 cts. per Space.	Value at 22.92 cts. per pound for Butter-fat.*	Overpaid, + Underpaid, -	Value per Space when 3 cts. is the average.
150	38	60	16.7	10.0	8.8	\$2.64	\$2.29	+ .35	2.6c.
151	162	111	16.8	18.6	8.7	4.86	4.26	+ .60	2.6
152	1498	976	22.3	217.7	6.9	44.94	49.90	-4.96	3.3
153	667	467	19.1	89.1	7.5	20.01	20.42	- .41	3.1
154	1152	751	19.4	145.6	7.9	34.56	33.37	+1.19	2.9
155	257	160	19.9	31.9	8.1	7.71	7.31	+ .40	2.8
156	370	259	20.3	52.6	7.0	11.10	12.06	- .96	3.3
157	294	189	21.7	40.9	7.2	8.82	9.37	- .55	3.2
158	1334	854	21.1	180.2	7.4	40.02	41.30	-1.28	3.1
159	983	699	19.5	136.3	7.2	29.49	31.24	-1.75	3.2
160	926	603	20.1	121.2	7.6	27.78	27.78	—	3.0
161	687	504	17.4	87.6	7.8	20.61	20.07	+ .54	2.9
162	317	226	20.0	45.1	7.0	9.51	10.34	- .83	3.3
163	524	342	17.3	59.1	8.9	15.72	13.55	+2.17	2.6
164	567	391	19.9	78.0	7.3	17.01	17.88	- .87	3.2
165	779	505	22.4	113.0	6.9	23.37	25.90	-2.53	3.3
166	1411	937	20.9	185.7	7.6	42.33	42.56	- .23	3.0
167	914	593	21.3	126.3	7.2	27.42	28.95	-1.53	3.2
168	236	159	19.1	30.4	7.8	7.08	6.97	+ .11	3.0
169	261	170	17.1	29.1	9.0	7.83	6.67	+1.16	2.6
170	465	317	21.2	67.3	6.9	13.95	15.43	-1.48	3.3
171	565	356	18.8	67.0	8.4	16.95	15.36	+1.59	2.7
172	528	358	18.8	67.3	7.8	15.84	15.42	+ .42	2.9
173	347	258	17.2	44.3	7.8	10.41	10.15	+ .26	2.9
174	827	579	17.2	99.6	8.3	24.81	22.83	+1.98	2.8
175	861	558	19.0	105.9	8.1	25.83	24.27	+1.56	2.8
176	376	285	16.5	47.0	8.0	11.28	10.77	+ .51	2.9
177	273	202	14.8	29.7	9.2	8.19	6.81	+1.38	2.5
178	1196	827	18.8	155.4	7.7	35.88	35.62	+ .26	3.0
Total,	57011	38103	—	7462.1	—	\$1710.33	\$1710.33	—	—

* One pound of butter-fat is nearly equal to 1.13 lbs. average butter.

The total number of spaces collected was 57,011, for which the creamery paid 3 cents per space, or a total of \$1,706.07. The cream contained 7,462.1 pounds of butter-fat, from which 9,023.5 pounds of butter were made. The average percentages of the butter-fat in the cream of the 78 patrons varied from 14.8 to 22.4, while the average of all the cream for the month was 19.6 per cent. of butter-fat. On the average, 7.6 spaces were required to make a pound of butter-fat, and the range was from 6.7 spaces to 9.6 spaces per pound of butter-fat. The column headed "cost at 3c. per space," shows what each patron actually received for his cream for the month. What he would have received if he had

been paid by the butter-fat which his cream contained, is shown in the next column, and the amounts underpaid or overpaid are shown in the last column but one. It will be observed that some patrons were very decidedly underpaid, and others were considerably overpaid during the month. One man, No. 127, would have received \$6.87 more for his cream if he had been paid by butter-fat, than he actually received by the space system. The last column shows what each patron's cream was worth per space when the creamery was paying 3 cents per space for all the cream used during the month. This ranged from 2.4 to 3.4 cents per space.

As a result of this month's trial, the creamery managers voted unanimously to adopt the butter-fat system of paying for cream, and they have been using this method for a year with satisfactory results.

Partly to satisfy ourselves that the results obtained at this particular creamery were not peculiar to it, and partly to show the managers of another creamery the unfairness of the space system, a week's test was made at the latter. The results are given in the table on the next page.

The total weight of the 8,814 spaces of cream was 6,661.7 pounds. The average percentage of butter-fat in the cream was 18.1; the lowest percentage of butter-fat was 14, and the highest, 21.75 per cent. The arrangement of the table is the same as the preceding. The fourth column from the last, headed "cost at 3c. per space," shows what was actually paid the patrons, the next column the amounts which they would have received if they had been paid by butter-fat system. The last column but one shows how much each patron was overpaid or underpaid during the week. The value per space of the cream on the butter-fat basis is shown in the last column; it ranged from 2.6 cents to 3.6 cents per space when the average price paid was 3 cents per space. This means that the patrons numbered 16, 19, 32 and 39 each received \$3.00 for each hundred spaces of cream which they furnished, when in reality the cream was worth only \$2.60 per hundred; and that at the same time the patrons numbered 5 and 40 were furnishing cream worth \$3.50 per hundred spaces, for which they received only \$3.00 per hundred. In other words, patrons 5 and 40 were each giving 50 cents per hundred spaces to their neighbors who were producing poorer cream.

Comparison of the Space and Butter-fat Systems of Valuation in a Creamery for one week in May, 1894.

Patron's Number.	Spaces of Cream.	Pounds of Cream.	Per Cent. Fat in Cream.	Pounds of Butter-fat.*	Spaces to 1 pound Butter-fat.*	Cost at 3 cts. per Space.	Value at 22 cents per pound for Butter-fat.*	Overpaid. + Underpaid. —	Value per Space when 3 cts. is the average.
1	510	324.1	20	64.8	7.9	\$15.30	\$14.23	+ 1.07	2.8c.
2	329	245.9	17	41.7	7.9	9.87	9.16	+ .71	2.8
3	450	331.8	18	59.7	7.5	13.50	13.10	+ .40	2.9
4	164	130.1	16.5	21.5	7.6	4.92	4.72	+ .20	2.9
5	58	52.5	17.5	9.2	6.3	1.74	2.02	— .28	3.5
6	438	315.6	19.5	61.5	7.1	13.14	13.50	— .36	3.1
7	105	72.9	21.75	15.9	6.6	3.15	3.49	— .34	3.3
8	129	83.9	20.5	17.2	7.5	3.87	3.77	+ .10	2.9
9	254	207.8	15.5	32.2	7.9	7.62	7.07	+ .55	2.8
10	163	123.4	16.25	20.0	8.1	4.89	4.39	+ .50	2.7
11	148	125.2	17.5	21.6	6.9	4.44	4.74	— .30	3.2
12	231	171.9	20	34.4	6.7	6.93	7.56	— .63	3.3
13	151	132.3	19	25.1	6.0	4.53	5.52	— .99	3.6
14	158	123.2	17.5	21.6	7.3	4.74	4.74	—	3.0
15	193	163.2	17.5	28.6	6.9	5.94	6.28	— .34	3.2
16	48	39.9	14	5.6	8.6	1.44	1.23	+ .21	2.6
17	105	95.7	14.75	14.1	7.4	3.15	3.09	+ .06	3.0
18	95	92.5	15.5	14.3	6.6	2.85	3.14	— .29	3.3
19	240	189.4	15	28.4	8.5	7.20	6.24	+ .96	2.6
20	201	179.3	16.25	29.1	6.9	6.03	6.39	— .36	3.2
21	45	40.0	17	6.8	6.6	1.35	1.50	— .15	3.3
22	196	160.8	16.75	26.9	7.3	5.88	5.91	— .03	3.0
23	151	131.5	14	18.4	8.2	4.53	4.04	+ .49	2.7
24	214	174.8	19	33.2	6.4	6.42	7.29	— .87	3.4
25	330	254.7	18.25	46.5	7.1	9.90	10.21	— .31	3.1
26	688	454.8	19	86.4	7.9	20.64	18.75	+ 1.89	2.7
27	104	75.3	24	18.1	5.7	3.12	3.93	— .81	3.7
28	406	267.7	20	53.5	7.6	12.18	11.61	+ .57	2.9
29	158	141.0	17	24.0	6.6	4.74	5.21	— .47	3.3
30	179	119.6	20.25	24.2	7.4	5.37	5.25	+ .12	2.9
31	170	131.9	16.25	21.4	7.9	5.10	4.64	+ .46	2.7
32	83	66.1	15.25	10.1	8.2	2.49	2.19	+ .30	2.6
33	48	37.8	17	6.4	7.5	1.44	1.39	+ .05	2.9
34	405	317.7	17.50	54.8	7.4	12.15	11.94	+ .21	2.9
35	68	47.7	21.0	10.0	6.8	2.04	2.17	— .13	3.2
36	180	124.4	19	23.6	7.6	5.40	5.12	+ .28	2.9
37	158	127.4	18.5	23.6	6.7	4.74	5.12	— .38	3.2
38	58	45.5	19.5	8.9	6.5	1.74	1.93	— .19	3.3
39	292	195.4	18.75	36.6	8.0	8.76	7.94	+ .82	2.6
40	136	105.3	20.75	21.8	6.2	4.08	4.76	— .68	3.5
41	433	329.1	20.50	67.5	6.4	12.99	14.71	— 1.72	3.4
42	137	112.8	18.0	20.3	6.7	4.11	4.43	— .32	3.2
Total,	8814	6661.5	—	1209.5	—	\$264.42	\$264.42	—	—

* One pound of butter-fat is nearly equal to 1.18 lbs. of average butter.

BUTTER-FAT METHOD OF PAYING FOR CREAM.

This method is fully described in Bulletin No. 119 of the Connecticut Experiment Station, pages 5-15; and in the Annual Report of that Station for 1894, pages 217-231. It may be briefly summarized as follows:

Apparatus needed.—A cream-gatherer's pail, spring balance weighing to about 60 pounds, sampling tube, set of collecting bottles for the dairy sample (these are best made of metal), and a set of larger bottles for the composite sample are needed for each route. The analysis of the cream is best made by the Babcock "apparatus for determining fat in milk and in cream."* This is furnished complete in various sizes, for power or hand use, by all dealers in creamery supplies. The total cost of apparatus needed to change from the space system to the butter-fat method of paying for cream will be from \$50 or \$75, or upwards, in accordance with the number of patrons, number of routes, and other conditions of the creamery.

Sampling and collecting the cream.—Each patron should be designated by a number, which number should be used on the sample bottle and in the gatherer's book. The patrons should be requested to draw their cream before the gatherer arrives. Each patron's cream should be thoroughly mixed by pouring at least twice from one vessel to another, or by the thorough use of an "agitator," before the sample is drawn. After the cream is thoroughly mixed and poured into the gatherer's pail, the stop-cock of the sampling tube is opened and the tube is slowly lowered into the pail of cream. It is then raised so as to allow the cream to run out and thus rinse the tube before taking the sample. The tube is again slowly lowered into the cream, the stop-cock is closed, the tube raised carefully, allowed to drain for a few seconds, wiped with a cloth and held over the sample bottle, the stop-cock is opened and the cream sample allowed to run into the bottle. Care in sampling is of the utmost importance. After taking the sample the cream is weighed and its weight recorded in the same way that spaces are recorded in the space system. At the creamery the small sample is poured into the larger "composite bottle" which bears the patron's number and to which a very little corrosive sublimate† or bi-chromate of potash has been added as a preservative.

* For description of this apparatus, see Wisconsin Experiment Station Report, 1890, pages 98-119, and the publications of the Connecticut Station above referred to.

† This is a very active poison and should be carefully kept and handled. For keeping cream not more than a week the bi-chromate of potash answers equally well and is not a dangerous poison. Its use is, therefore, to be preferred.

Analysis of the cream. Book-keeping.—After several collections have been made the composite samples are analyzed and the percentages of butter-fat in the cream are determined and recorded. The analyses can be made three or four times during the month. In practice in most creameries they are made each week or four times during the month.

The weight of the cream collected multiplied by the percentage of butter-fat which it contained gives the weight of butter-fat. The amount of money to be paid the patrons divided by the total number of pounds of butter-fat collected gives the price per pound for the month. The number of pounds of butter-fat furnished by each patron multiplied by the price paid per pound gives, as in the space system, the amount due each patron.

WHY THE BUTTER-FAT SYSTEM FOR PAYING FOR CREAM IS PREFERABLE TO THE SPACE SYSTEM.

The chief, and it seems to us fatal, objection to the use of the space system as the basis of payment for cream furnished by the patrons of creameries is its manifest unfairness and injustice. As is shown in both of the cases of the creameries examined as above, the cream furnished by patrons varies greatly in quality. One patron receives \$3.00 per hundred spaces for cream which is worth only \$2.50 at the average rate at which the creamery is paying, while another person receives only \$3.00 for the same amount of cream which is worth \$3.50. The butter-fat system involves somewhat more labor at the creamery, but all creameries which have adopted the butter-fat method for payment, so far as we know, are persuaded that this extra labor is amply repaid in the greater fairness and satisfaction to patrons as well as by the greater economy of the butter production. Under the space system, creameries find it necessary to make occasional churnings of the cream of individual patrons, and in some instances, at least, the time consumed for these occasional and imperfect tests is greater than is needed for the systematic and accurate tests by the butter-fat method.

If creamery managers will do business upon a thoroughly square basis there is no question that some other method than the space system must be adopted. There is to-day no better and fairer method known than the system of payment for cream by its butter-fat content. Believing this to be a very important matter for the farming community in general, the Station is prepared to assist any creamery that wishes to adopt the butter-fat method.

RESULTS OF ANALYSES OF FODDERS AND FEEDING STUFFS.

BY CHAS. D. WOODS.

In connection with the work of the Station, analyses of the following miscellaneous feeding stuffs have been made by the Station chemists. For the most part the analyses were made in connection with feeding experiments or experiments upon the growth of plants. In no case were they undertaken merely to increase the amount of this class of data. The methods of analyses recommended by the Association of Official Agricultural Chemists were employed.

The results of the analyses as calculated to water content at harvest or at the time of analyses are given in table 1, page 21, which follows the description of samples. In this table the materials are grouped somewhat according to their water content at time of taking samples, as follows: Green fodders; silage; cured hay and fodder; grain; and milling products. This order is also observed in the descriptions of samples.

The results calculated to water-free substance (dry matter) as the basis are given in table 2, page 23.

The fuel value of a pound of each of the feeding stuffs as given in the tables was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6, and the number of hundredths of a pound of fat by 42.2, and taking the sum of these three products as the number of calories of potential energy in the materials.*

DESCRIPTION OF SAMPLES.

In the description of samples the order of arrangement is the same as in the tables.

GREEN FODDERS.

1359-1362, *Orchard Grass* (*Dactylis glomerata*).—Grown in the grass garden of the Station in 1894. The samples were all taken June 18th, at which time the

* See paper on Fuel Value of Feeding Stuffs in Report of this Station for 1890, pp. 174-181.

seed was just beginning to form. No. 1359 was grown without the use of fertilizers. Growth light and spindly; pale colored. No. 1360 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth much resembled that of 1359. No. 1361 was grown on a plot to which mixed minerals were applied as in 1360 and had in addition 160 pounds of nitrate of soda per acre. The grass was of good color and the growth was much heavier than that of 1359 and 1360. No. 1362 was grown on a plot to which mixed minerals were applied as in 1360 and had in addition 480 pounds of nitrate of soda. Heavy, dense growth of good color.

1351-1354, *Tall Meadow Fescue Grass (Festuca elatior)*.—Grown in the grass garden of the Station in 1894. The samples were taken June 27th, at which time seed was beginning to form. No. 1351 was from a plot without fertilizers. Light, spindly growth of pale color. No. 1352 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth resembled that of 1351. No. 1353 was grown on a plot to which mixed minerals were applied as in 1352 and had in addition 160 pounds of nitrate of soda per acre. Quite heavy growth of fair color. The bottom growth was quite thick. No. 1354 was grown on a plot to which mixed minerals were applied as in 1352 and had in addition 480 pounds of nitrate of soda. Heavy, dense growth of dark green color. Under growth thick.

1347-1350, *Tall Meadow Oat Grass (Avena elatior)*.—Grown in Station grass garden in 1894. Samples were taken June 18th, at which time seed was beginning to form. No. 1347 was grown without the use of fertilizers. Light, spindly growth of pale color. No. 1348 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth resembled 1347 except grass was a little more mature. No. 1349 was grown on a plot to which mixed minerals were applied as in 1348 and had in addition 160 pounds of nitrate of soda per acre. Fair growth of good color. No. 1350 was grown on a plot to which mixed minerals were applied as in 1348 and had in addition 480 pounds of nitrate of soda. Thick, heavy growth of good color.

1355-1358, *Timothy (Phleum pratense)*.—Grown in the Station grass garden in 1894. The samples were taken July 3, 1894, at which time the grass was just past full bloom. No. 1355 was grown without the use of fertilizers. Light, thin growth. No. 1356 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth much like that of 1355. No. 1357 was grown on a plot to which mixed minerals were applied as in 1356 and had in addition 160 pounds of nitrate of soda per acre. Quite heavy growth. No. 1358 was grown on a plot to which mixed minerals were applied as in 1356 and had in addition 480 pounds of nitrate of soda. Heavy, dense growth.

1370, 1372, 1374, 1376, *Barley Fodder*.—As used in digestion experiments.* The samples were taken from the field from October 8th to October 15th. No.

* See article on Digestion Experiments beyond in this Report.

1370, cut October 8, 1894, nearly grown, in early bloom; 1372, cut October 11th, in bloom, some seeding; 1374, cut October 13th, early seeding; 1376, cut October 15th, seeding but still succulent.

1369, 1371, 1373, 1375. *Barley and Pea Fodder*, as used in digestion experiments.* The samples were taken from the field from October 8th to October 15th. No. 1369, cut October 8th, barley nearly grown, in early bloom; peas beginning to blossom. No. 1371, cut October 11th, barley nearly grown, in bloom and beginning to seed; peas have many blossoms. No. 1373, cut October 13th, barley early seeding; peas full grown and full bloom. No. 1375, cut October 15th, barley early seeding, still succulent; peas mostly still green and in bloom.

1366-1368, *Cow Pea Vines (Dolichos sinensis)*.—Good growth on all plots. Samples taken September 18, 1894. No. 1366 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1367 was grown on a plot to which mixed minerals were applied as in 1366 and had in addition 160 pounds of nitrate of soda per acre. No. 1368 was grown on a plot to which mixed minerals were applied as in 1366 and had in addition 480 pounds of nitrate of soda per acre.

1341-1343, *Scarlet Clover (Trifolium incarnatum)*, used in digestion experiments.* Samples were taken May 26th to June 2d.

ENSILAGE.

1262, *Corn Ensilage*.—Samples were taken in connection with milch cow ration No. 18.

CURED FODDERS AND HAYS.

1274, *Fodder*.—The fodder consisted of about 500 pounds of oat straw and 75 pounds bog hay, mixed as it was run through the cutter. Sample was taken of each separately and combined in the above proportions at the laboratory. Taken in connection with milch cow ration No. 20.

1269, 1279 and 1289, *Corn Stover*.—Samples taken in connection with milch cow rations Nos. 19, 22 and 24 respectively.

1276 and 1278, *Oat Hay*.—Samples taken in connection with milch cow rations Nos. 20 and 22 respectively.

1297, *Timothy Hay. Early cut*.—Samples taken in connection with milch cow ration No. 26.

1325-1328, *Early Cut Hay. Mixed grasses*.—Sample taken in connection with digestion experiments Nos. 1 to 4. (See article beyond on digestion experiments).

1263, 1264, 1268, 1277 and 1290, *Hay from Mixed Grasses*.—Nos. 1264 and 1290 were timothy and red-top hay, about three-fourths timothy and one-fourth red-top. Samples were taken in connection with milch cow rations Nos. 18 and 24. Nos. 1263, 1268 and 1277 were ordinary hay from mixed grasses. Samples were taken in connection with milch cow rations Nos. 18, 19 and 22.

1288, *Clover Hay*.—Samples were taken in connection with milch cow ration No. 24. The hay was about three-fourths clover and one-fourth mixed grasses.

*See article on Digestion Experiments beyond in this Report.

SEEDS.

1363-1365, *Soy Beans (Soja hispida)*.—Grown by the Station in 1892. No. 1363 was grown upon a plot which received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1364 was grown upon a plot which received, in addition to the same mixed minerals as 1109, nitrate of soda at the rate of 160 pounds per acre. No. 1111 was from a plot which received, in addition to the same mixed minerals as 1109, 480 pounds of nitrate of soda per acre. No. 1341, cut May 26th, at which time the clover was not quite in full bloom; 1342, cut May 28th, in full bloom; 1343, cut June 2d, a little past full bloom, lower half of heads beginning to seed.

1303, 1340, *Oats and Peas*.—These were grown by the Station in 1893 for the seed. They were used in digestion experiments, and for further description of samples see article on digestion experiments beyond.

MILLING AND BY-PRODUCTS.

1265, 1300 and 1305, *Corn Meal*.—From western grown corn. No. 1265 was used in milch cow ration No. 18; 1300 and 1305 in digestion experiments.

1273, 1281, 1283, 1287 and 1294, *Corn and Cob Meal*.—All Connecticut grown. Samples taken in connection with milch cow rations Nos. 20, 22, 23, 24 and 25 respectively.

1272, *Cob and Rye Meal*.—Corn on the cob and rye, ground together in the proportions of 14 bushels of corn on the ear and 6 bushels of rye. Samples taken in connection with milch cow ration No. 19.

1266, 1271, 1275, 1280 and 1284, *Wheat Bran*.—Samples taken in connection with milch cow rations Nos. 18, 19, 20, 22 and 23. No. 1275 is a winter wheat bran.

1299, *Wheat Middlings*.—Samples taken in connection with milch cow ration No. 26.

1291, *Linseed Meal*.—Sample taken in connection with milch cow ration No. 25.

1302, *Linseed Mixture*.—Used in digestion experiments (see beyond). The mixture consisted of three parts old process linseed meal and one part corn meal. The corn meal was from the same lot as samples No. 1300 and 1305 above.

1282, 1286, 1293, *Chicago Gluten Meal*.—Samples taken in connection with milch cow rations Nos. 23, 24 and 25 respectively.

1270, *Cream Gluten Meal*.—Samples taken in connection with milch cow ration No. 19.

1298, *Peoria Gluten Feed*.—Samples taken in connection with milch cow ration No. 26.

1296, *Sheep Feed*.—The grain and ensilage used by Mr. Chas. Lyman of Middlefield for fattening sheep in the winter of 1893-94. The mixture was as follows: Corn ensilage 2,400 pounds, whole corn 500 pounds, pea meal 1,000 pounds, and wheat middlings 800 pounds. This, together with about 400 pounds of hay a day, made a day's ration for 1,300 sheep.

TABLE I.

Proximate Composition of Fodders and Feeding Stuffs. Results of Analyses Herewith Reported, Calculated to Water Content at Time of Taking Sample.

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Value.
	<i>Green Fodders.</i>	%	%	%	%	%	%	Calories per lb.
1359	Orchard grass, - -	63.83	2.73	1.10	16.14	13.38	2.82	645
1360	Orchard grass, - -	65.50	2.47	.98	14.91	13.16	2.98	605
1361	Orchard grass, - -	66.97	2.61	1.17	14.43	11.98	2.84	585
1362	Orchard grass, - -	71.93	2.98	.97	11.68	10.17	2.27	500
	Average, - - -	67.06	2.69	1.06	14.29	12.17	2.73	570
1351	Tall meadow fescue grass, -	68.63	1.86	.77	12.61	13.93	2.20	555
1352	Tall meadow fescue grass, -	67.72	1.93	.77	16.22	11.02	2.34	570
1353	Tall meadow fescue grass, -	72.43	1.90	.75	12.65	10.24	2.03	490
1354	Tall meadow fescue grass, -	76.85	2.22	.73	9.18	9.04	1.98	410
	Average, - - -	71.41	1.98	.75	12.66	11.06	2.14	505
1347	Tall meadow oat grass, -	66.40	2.68	1.02	15.13	12.34	2.43	600
1348	Tall meadow oat grass, -	67.31	2.47	1.04	14.41	12.24	2.53	585
1349	Tall meadow oat grass, -	69.18	2.67	.98	14.04	11.07	2.06	555
1350	Tall meadow oat grass, -	68.99	3.57	1.05	13.20	11.07	2.12	560
	Average, - - -	67.97	2.85	1.02	14.20	11.68	2.28	575
1355	Timothy, - - -	66.65	3.86	1.06	14.49	12.07	1.87	605
1356	Timothy, - - -	67.13	2.23	.87	17.28	10.42	2.07	590
1357	Timothy, - - -	67.60	6.31	1.03	10.92	12.29	1.85	590
1358	Timothy, - - -	69.28	2.40	1.11	14.02	11.50	1.69	565
	Average, - - -	67.66	3.70	1.02	14.18	11.57	1.87	585
1370	Barley, - - -	78.05	3.52	.87	9.80	5.84	1.92	395
1372	Barley, - - -	76.70	3.56	.90	9.11	7.48	2.25	413
1374	Barley, - - -	76.57	3.68	.91	10.32	6.37	2.15	420
1376	Barley, - - -	75.31	3.50	.91	11.96	6.52	1.80	445
	Average, - - -	76.66	3.56	.90	10.30	6.55	2.03	420
1369	Barley and peas, - -	81.77	3.80	.81	7.33	4.69	1.60	330
1371	Barley and peas, - -	80.62	3.71	.77	7.98	5.10	1.82	345
1373	Barley and peas, - -	79.63	4.22	.98	8.64	4.95	1.58	370
1375	Barley and peas, - -	79.89	3.91	.71	8.72	5.22	1.55	360
	Average, - - -	80.47	3.91	.81	8.16	4.99	1.66	351
1366	Cow pea vines, - -	85.55	2.72	.55	5.94	3.38	1.86	250
1367	Cow pea vines, - -	84.00	2.84	.68	7.13	3.35	2.00	270
1368	Cow pea vines, - -	84.99	3.01	.61	6.44	3.04	1.91	255
	Average, - - -	84.85	2.86	.61	6.50	3.26	1.92	260
1341	Scarlet clover, - -	87.31	2.48	.64	5.00	3.24	1.33	225
1342	Scarlet clover, - -	83.89	2.73	.65	6.96	4.37	1.40	285
1343	Scarlet clover, - -	84.45	2.91	.72	6.16	4.20	1.56	275
	Average, - - -	85.22	2.71	.67	6.04	3.93	1.43	260
	<i>Ensilage.</i>							
1262	Corn ensilage, - -	69.32	2.84	1.29	19.75	5.18	1.62	570
	<i>Cured Hay and Fodders.</i>							
1274	Fodder, mostly stover, -	27.05	5.54	2.09	34.90	25.85	4.57	13.20

* For description of samples, see pages 17-20.

TABLE I.—(Continued.)

Lab. No.	KIND.*	Water.	Pro- tein.	Fat.	Nit.- free Ext.	Fiber.	Ash.	Fuel Value.
	<i>Cured Hay and Fodders. (Continued.)</i>	%	%	%	%	%	%	Calo- ries per lb.
1269	Corn stover, -	14.05	5.80	2.22	44.16	28.73	5.04	1555
1279	Corn stover, -	7.49	9.88	2.30	51.56	22.11	6.66	1650
1289	Corn stover, -	15.94	7.80	1.86	41.55	26.06	5.89	1405
	Average, -	12.49	7.83	2.13	45.77	25.93	5.85	1565
1276	Oat hay, -	16.23	7.62	3.36	42.20	25.03	5.56	1535
1278	Oat hay, -	6.21	10.75	3.48	43.16	30.97	5.43	1725
	Average, -	11.22	9.18	3.42	42.68	28.00	5.50	1630
1297	Timothy hay, -	10.58	7.33	2.83	45.23	28.45	5.58	1650
1325	Hay, early cut, -	8.78	10.94	3.69	40.27	31.11	5.21	1685
1326	Hay, early cut, -	8.13	11.44	3.62	41.71	30.08	5.02	1690
1327	Hay, early cut, -	8.47	11.11	3.58	39.25	32.29	5.30	1685
1328	Hay, early cut, -	7.85	11.24	3.48	41.37	30.67	5.39	1690
	Average, -	8.31	11.18	3.59	40.65	31.04	5.23	1690
1263	Hay, mixed grasses, -	13.64	6.06	3.04	45.50	27.37	4.39	1595
1264	Hay, mixed grasses, -	13.22	5.74	2.99	43.23	30.39	4.43	1605
1268	Hay, mixed grasses, -	14.18	9.09	3.01	42.60	25.92	5.20	1570
1277	Hay, mixed grasses, -	7.25	8.81	3.45	47.56	27.04	5.89	1700
1290	Hay, mixed grasses, -	10.79	5.91	2.52	46.25	30.25	4.28	1640
	Average, -	11.82	7.12	3.00	45.03	28.19	4.84	1622
1288	Clover hay, -	11.57	21.40	3.79	34.00	22.61	6.63	1615
	<i>Seeds.</i>							
1363	Soy beans, -	14.53	34.36	15.48	26.17	4.25	5.21	1855
1364	Soy beans, -	11.20	35.57	16.05	27.52	4.80	4.86	1935
1365	Soy beans, -	15.33	36.00	15.37	24.92	3.85	4.53	1850
	Average, -	13.69	35.31	15.63	26.20	4.30	4.87	1880
1303	Oats and peas, -	11.55	23.88	2.53	52.05	6.62	3.37	1640
1340	Oats and peas, -	11.38	22.25	2.48	52.95	7.65	3.29	1640
	Average, -	11.46	23.07	2.51	52.50	7.13	3.33	1640
	<i>Milling and By-Products.</i>							
1265	Corn meal, -	11.73	10.31	4.11	71.55	1.10	1.20	1715
1300	Corn meal, -	12.44	10.19	4.31	70.55	1.27	1.24	1705
1305	Corn meal, -	12.39	10.00	4.78	70.31	1.28	1.24	1715
	Average, -	12.18	10.17	4.40	70.80	1.22	1.23	1710
1273	Corn and cob meal, -	10.14	11.25	3.81	68.90	4.45	1.45	1735
1281	Corn and cob meal, -	12.71	9.88	3.02	68.69	4.42	1.28	1670
1283	Corn and cob meal, -	11.68	11.06	3.58	67.18	5.18	1.32	1705
1287	Corn and cob meal, -	16.56	10.55	3.52	64.90	3.01	1.46	1605
1294	Corn and cob meal, -	12.28	11.38	3.42	67.08	4.38	1.46	1685
	Average, -	12.67	10.83	3.47	67.35	4.29	1.39	1680
1272	Cob and rye meal, -	15.83	9.99	3.10	67.96	1.66	1.46	1610
1266	Wheat bran, -	7.46	16.75	5.14	55.96	8.71	5.98	1730
1271	Wheat bran, -	9.28	20.44	6.01	50.51	8.82	4.94	1735
1275	Wheat bran, -	8.30	17.13	4.77	55.35	8.76	5.69	1715
1280	Wheat bran, -	8.25	19.69	4.74	52.64	8.98	5.70	1710
1284	Wheat bran, -	8.41	18.25	5.28	53.08	9.24	5.74	1725
	Average, -	8.34	18.45	5.19	53.51	8.90	5.61	1725

* For description of samples, see pages 17-20.

TABLE I.—(Continued.)

Lab. No.	KIND.*	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Value.
	<i>Milling and By-Products.</i>	%	%	%	%	%	%	Calories per lb.
	(Continued.)							
1299	Wheat middlings, -	10.03	20.88	6.44	49.96	7.95	4.74	1735
1291	Linseed meal, -	9.23	44.25	3.84	30.19	6.63	5.86	1690
1302	Linseed mixture, -	10.50	30.06	5.53	43.60	5.96	4.35	1715
1267	Cotton seed meal, -	7.30	48.19	9.13	24.09	4.22	7.07	1905
1292	Cotton seed meal, -	7.32	47.38	9.44	24.40	4.48	6.89	1820
	Average, -	7.31	47.78	9.29	24.29	4.35	6.98	1865
1282	Chicago gluten meal, -	9.83	33.81	4.02	49.71	1.76	.87	1755
1286	Chicago gluten meal, -	8.59	40.09	6.24	40.67	3.25	1.16	1825
1293	Chicago gluten meal, -	8.64	33.38	4.66	50.33	2.12	.87	1790
	Average, -	9.02	35.76	4.97	46.90	2.38	.97	1790
1270	Cream gluten meal, -	8.16	39.81	14.25	35.46	1.43	.89	2030
1298	Peoria gluten feed, -	5.56	26.13	15.64	41.30	10.41	.96	2105
1296	Sheep feed, -	44.45	9.74	2.13	33.06	8.04	2.58	1055

TABLE 2.

Proximate Composition of Fodders and Feeding Stuffs—Results of Analyses Herewith Reported, Calculated to Water-free Substance (Dry Matter).

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Value.
	<i>Green Fodders.</i>	%	%	%	%	%	Calories per lb.
1359	Orchard grass, - - -	7.54	3.04	44.63	36.98	7.81	1785
1360	Orchard grass, - - -	7.17	2.83	43.21	38.14	8.65	1765
1361	Orchard grass, - - -	7.91	3.55	43.67	36.27	8.60	1780
1362	Orchard grass, - - -	10.61	3.45	41.61	36.24	8.00	1790
	Average, - - -	8.30	3.22	43.28	36.91	8.29	1780
1351	Tall meadow fescue grass, -	5.94	2.44	40.19	44.40	7.03	1765
1352	Tall meadow fescue grass, -	5.98	2.39	50.25	34.13	7.25	1775
1353	Tall meadow fescue grass, -	6.89	2.72	45.89	37.13	7.37	1785
1354	Tall meadow fescue grass, -	9.60	3.13	39.65	39.07	8.55	1774
	Average, - - -	7.10	2.67	44.00	38.68	7.55	1775
1347	Tall meadow oat grass, -	7.98	3.02	45.04	36.71	7.25	1795
1348	Tall meadow oat grass, -	7.57	3.17	44.08	37.44	7.74	1785
1349	Tall meadow oat grass, -	8.68	3.19	45.55	35.91	6.67	1805
1350	Tall meadow oat grass, -	11.52	3.39	42.56	35.70	6.85	1805
	Average, - - -	8.94	3.19	44.80	36.44	7.13	1800
1355	Timothy, - - -	11.58	3.18	43.44	36.19	5.61	1825
1356	Timothy, - - -	6.79	2.67	52.55	31.69	6.30	1800
1357	Timothy, - - -	19.50	3.18	33.67	37.94	5.71	1825
1358	Timothy, - - -	7.82	3.60	45.67	37.42	5.49	1655
	Average, - - -	11.42	3.16	43.83	35.81	5.78	1775

* For description of samples, see pages 17-20.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Pro- tein.	Fat.	Nit.- free Ext.	Fiber.	Ash.	Fuel Value.
	<i>Green Fodders.</i> (Continued.)	%	%	%	%	%	Calo- ries per lb.
1373	Barley, - - - -	16.06	3.96	44.66	26.61	8.71	1790
1372	Barley, - - - -	15.29	3.87	39.11	32.12	9.61	1770
1374	Barley, - - - -	15.71	3.88	44.04	27.19	9.18	1780
1376	Barley, - - - -	14.18	3.69	48.44	26.40	7.29	1810
	Average, - - - -	15.31	3.85	44.06	28.08	8.70	1790
1369	Barley and peas, - - - -	20.86	4.44	40.20	25.72	8.78	1800
1371	Barley and peas, - - - -	19.16	3.99	41.16	26.32	9.37	1780
1373	Barley and peas, - - - -	20.74	4.79	42.44	24.28	7.75	1830
1375	Barley and peas, - - - -	19.44	3.53	43.36	25.96	7.71	1800
	Average, - - - -	20.05	4.19	41.79	25.57	8.40	1805
1366	Cow pea vines, - - - -	18.81	3.84	41.09	23.38	12.88	1710
1367	Cow pea vines, - - - -	17.81	4.28	44.49	20.95	12.47	1725
1368	Cow pea vines, - - - -	20.05	4.04	42.88	20.28	12.75	1680
	Average, - - - -	18.89	4.05	42.82	21.54	12.70	1705
1341	Scarlet clover, - - - -	19.58	5.03	39.37	25.52	10.50	1780
1342	Scarlet clover, - - - -	16.92	4.06	43.20	27.10	8.72	1790
1343	Scarlet clover, - - - -	18.68	4.65	39.60	27.04	10.03	1780
	Average, - - - -	18.40	4.58	40.72	26.55	9.75	1785
	<i>Ensilage.</i>						
1262	Corn ensilage, - - - -	9.26	4.21	64.37	16.88	5.28	1860
	<i>Cured Hay and Fodders.</i>						
1274	Fodder, mostly stover, - - - -	7.59	2.86	47.85	35.44	6.26	1815
1269	Corn stover, - - - -	6.75	2.58	51.38	33.43	5.86	1815
1279	Corn stover, - - - -	10.68	2.49	55.73	23.90	7.20	1785
1289	Corn stover, - - - -	9.28	2.21	49.43	32.07	7.01	1780
	Average, - - - -	8.90	2.43	52.18	29.80	6.69	1795
1276	Oat hay, - - - -	9.10	4.01	50.37	29.88	6.64	1830
1278	Oat hay, - - - -	11.46	3.71	46.02	33.02	5.79	1840
	Average, - - - -	10.28	3.86	48.20	31.45	6.21	1835
1297	Timothy hay, - - - -	8.20	3.16	50.58	31.82	6.24	1815
1325	Hay, early cut, - - - -	11.99	4.04	44.15	34.11	5.71	1845
1326	Hay, early cut, - - - -	12.45	3.94	45.41	32.74	5.46	1850
1327	Hay, early cut, - - - -	12.14	3.91	42.88	35.28	5.79	1845
1328	Hay, early cut, - - - -	12.20	3.78	44.89	33.28	5.85	1835
	Average, - - - -	12.20	3.92	44.33	33.85	5.70	1845
1263	Hay from mixed grasses, - - - -	7.02	3.52	52.68	31.70	5.08	1850
1264	Hay from mixed grasses, - - - -	6.61	3.44	49.83	35.02	5.10	1845
1268	Hay from mixed grasses, - - - -	10.59	3.51	49.64	30.20	6.06	1830
1277	Hay from mixed grasses, - - - -	9.50	3.72	51.27	29.16	6.35	1830
1290	Hay from mixed grasses, - - - -	6.63	2.82	51.84	33.91	4.80	1835
	Average, - - - -	8.07	3.40	51.05	32.00	5.48	1840
1288	Clover hay, - - - -	24.20	4.28	38.45	25.57	7.50	1825
	<i>Seeds.</i>						
1363	Soy beans, - - - -	40.20	18.10	30.62	4.98	6.10	2175
1364	Soy beans, - - - -	40.05	18.07	30.99	5.41	5.48	2180
1365	Soy beans, - - - -	42.53	18.16	29.43	4.53	5.35	2185
	Average, - - - -	40.93	18.11	30.35	4.97	5.64	2180

* For description of samples, see pages 17-20.

TABLE 2.—(Continued.)

Lab. No.	KIND.*	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Value.
	<i>Seeds.</i> (Continued.)	%	%	%	%	%	Calories per lb.
1303	Oats and peas, - - -	27.00	2.86	58.85	7.48	3.81	1855
1340	Oats and peas, - - -	25.11	2.80	59.75	8.63	3.71	1855
	Average, - - -	26.05	2.83	59.30	8.06	3.76	1855
	<i>Milling and By-Products.</i>						
1265	Corn meal, - - -	11.68	4.66	81.05	1.25	1.36	1945
1300	Corn meal, - - -	11.64	4.92	80.57	1.45	1.42	1950
1305	Corn meal, - - -	11.41	5.46	80.25	1.46	1.42	1960
	Average, - - -	11.57	5.01	80.63	1.39	1.40	1950
1273	Corn and cob meal, - - -	12.52	4.24	76.68	4.95	1.61	1930
1281	Corn and cob meal, - - -	11.32	3.46	78.69	5.06	1.47	1915
1283	Corn and cob meal, - - -	12.52	4.05	76.07	5.87	1.49	1930
1287	Corn and cob meal, - - -	12.65	4.22	77.77	3.61	1.75	1925
1294	Corn and cob meal, - - -	12.97	3.90	76.48	4.99	1.66	1920
	Average, - - -	12.40	3.96	77.14	4.90	1.60	1925
1272	Cob and rye meal, - - -	11.87	3.68	80.75	1.97	1.73	1915
1266	Wheat bran, - - -	18.10	5.56	60.47	9.41	6.46	1875
1271	Wheat bran, - - -	22.53	6.63	55.67	9.72	5.45	1915
1275	Wheat bran, - - -	18.68	5.20	60.36	9.55	6.21	1865
1280	Wheat bran, - - -	21.46	5.17	57.37	9.79	6.21	1865
1284	Wheat bran, - - -	19.93	5.76	57.95	10.09	6.27	1880
	Average, - - -	20.14	5.67	58.36	9.71	6.12	1880
1299	Wheat middlings, - - -	23.21	7.16	55.53	8.83	5.27	1930
1291	Linseed meal, - - -	48.75	4.23	33.26	7.30	6.46	1840
1302	Linseed mixture, - - -	33.59	6.17	48.72	6.66	4.86	1910
1267	Cotton seed meal, - - -	51.99	9.85	25.98	4.55	7.63	1955
1292	Cotton seed meal, - - -	51.12	10.19	26.43	4.83	7.43	1955
	Average, - - -	51.55	10.02	26.21	4.69	7.53	1955
1282	Chicago gluten meal, - - -	37.49	4.46	55.13	1.95	.97	1950
1286	Chicago gluten meal, - - -	43.86	6.83	44.49	3.56	1.26	1995
1293	Chicago gluten meal, - - -	36.54	5.10	55.09	2.32	.95	1960
	Average, - - -	39.30	5.46	51.57	2.61	1.06	1970
1270	Cream gluten meal, - - -	43.36	15.52	38.60	1.56	.96	2205
1298	Peoria gluten feed, - - -	27.67	16.56	43.73	11.02	1.02	2230
1296	Sheep feed, - - -	17.53	3.83	59.52	14.47	4.65	1865

* For description of samples, see pages 17-20.

A STUDY OF RATIONS FED TO MILCH COWS IN CONNECTICUT.

BY CHAS. D. WOODS AND C. S. PHELPS.

The study of rations fed to milch cows in this State, which was begun in the winter of 1892-93, has been continued, and at the time of this writing (December, 1894,) the third winter's examination of the actual feeding practice of Connecticut dairymen has been commenced. The first winter's work (1892-93) was described in detail in the Report of this Station for 1893, pp. 69-115. Some account* of this study was given at the winter meeting of the State Board of Agriculture at Hartford, in December, 1893, and it was the subject of Bulletin 13 of this Station. The results of the second winter's work (1893-94) are here reported.

Each herd was selected after a personal inspection, or after sufficient correspondence to satisfy ourselves of its fitness for the proposed test, and a representative of the Station was present during the whole period of each test and attended to the details of the experiment, such as weighing the feeding stuffs and taking samples for analyses, and weighing, sampling and determining the butter-fat in the milk. This work was faithfully performed by Mr. E. B. Fitts, at that time the Station Assistant in Farm Experiments.

In the first winter's work (1892-93), which was regarded as preliminary to an investigation that might extend over a series of years, it was thought better to examine a relatively large number of herds, each during a short period, than to make the periods longer and the number of herds less. Sixteen herds were visited and a five-days' test was made of each.

In the second winter's work, 1893-94, six different herds were visited, and in four cases the time of study of the management and products of each herd was extended to twelve days. The analyses of the feeding stuffs were made at once and the weights of nutrients in the rations as fed were calculated. In three

* Notes on Feeding Dairy Stock, by Chas. D. Woods; Report Conn. Board of Agriculture, 893, pp. 182-199.

instances other rations were thereupon suggested by us as being better than the ones that had been used. The owners gradually changed the food to the ration thus proposed, and after an interval of four weeks from the close of the first test, another twelve-days' test was made of the same herd. A comparison was thus made of the yields of milk and butter-fat with the two different rations.

The chief points upon which information was obtained were:—

Number of animals in the herd.—In considering the number of animals, only those which came into the test were included. Usually these were all of the cows on the farm which were in milk at the time of the test.

Breed, age and approximate weight of each cow.—The breed and age were obtained as accurately as possible from the owner. Since it was not practicable to take to the farm scales large enough on which to weigh the cows, the weights were estimated. This estimation was made in each case by the Station representative, and it is hoped that the errors of judgment may run more or less equally through all the herds examined.

Number of months since last calf.—In most cases the time at which the cow dropped her last calf was known.

Number of months till due to calve.—There was, of course, more or less uncertainty in this regard.

Weights of milk-flow for the five days.—The milk of each cow at each milking was weighed as soon as milked, to the nearest tenth of a pound, by the Station representative.

Percentages and amounts of butter-fat in the milk.—A sample of the milk of each cow, at each milking, was taken for the determination of the quantity of butter-fat. The Babcock method of fat determination was employed. From the percentages of butter-fat in the milk, and the total weights of the milk, the daily yields of butter-fat were obtained.

Kinds and weights of foods used.—The feeder was requested to use the same kinds and amounts of feeding stuffs during the test period as he had previously used. The quantity for each animal was weighed by the Station representative just before feeding. Any portions of the food left uneaten by the cows were carefully weighed, and due allowance was made for these uneaten residues in estimating the amounts daily eaten. During the test, usually

on the third day, samples of each feeding stuff used were carefully taken and at once sent to the laboratory for analysis. From the results of the analyses and the weights fed, the total nutrients (protein, fat, nitrogen-free extract and fiber) fed each day were calculated. By the use of digestion coefficients, estimates were made of the weights of digestible nutrients in each day's ration.

The names and post-office addresses of the owners of the herds studied by the Station are given in the following list, together with the dates at which the Station representative was at the farm. At the left, in the first column of figures, is a reference number for each test. In the remaining tables, and in the discussion, the herds entering into the tests and the rations fed are designated by these reference numbers.

*Names and Post-office Addresses of Owners of Herds Studied,
Dates at which they were Visited and Reference
Numbers of Tests.*

NUMBER OF TEST.	NAME AND P. O. ADDRESS OF OWNER.	DATE OF TEST.
18, - -	W. S. Crane, Willimantic.	1893. Dec. 4-16.
19, - -	Harvey S. Ellis, Vernon Center.	Dec. 18-30. 1894.
20, - -	Clifton Peck, Lebanon.	Jan. 2-13.
21, - -	Same herd as No. 18.	Jan. 15-27.
22, - -	C. H. Lathrop, North Franklin.	Jan. 29-Feb. 10.
23, - -	Same herd as No. 20.	Feb. 12-24.
24, - -	W. F. Maine, South Windham.	Feb. 26-March 3.
25, - -	Same herd as No. 22.	March 5-17.
26, - -	Charles G. Nichols, West Willington.	March 19-24.

The following abbreviations are used in the tables:

Abbreviations Used in Report of Rations Fed to Milch Cows.

Ay.=Ayrshire.	Gy.=Guernsey.	P.=Pure Breed.
Dev.=Devon.	Hol.=Holstein.	R.=Registered.
Dur.=Durham.	Jy.=Jersey.	Sw.=Swiss.
G.=Grade.	Nat.=Native.	

Tables 3 to 11 inclusive contain the results, in considerable detail, of the studies of the different herds. They are all alike in arrangement, and a description of one will serve for all. Each table contains the condensed results of a test. Table 3, for instance, gives the statistics for test No. 18.

The first part of the upper table gives a reference number of each animal, its breed, age, weight and number of months since last calf. The smallest daily milk flow, the greatest daily milk flow and the average daily yield of milk for the period of the test are given in the next three columns. In the three following columns are given the lowest, highest and average percentages of fat found in the daily milk of each cow for the period. The figures were obtained by adding together the several daily determinations and taking the average, hence this actual average is not always half way between the highest and lowest. The yield of fat is given in the last three columns of the first or upper part of the table. The minimum and maximum yields of fats were obtained by multiplying each day's milk by its percentage of fat; the lowest number thus obtained gives the minimum daily yield of fat, and the largest the maximum yield of fat. It is to be noted that these numbers are not the same as would have been obtained by multiplying the minimum and maximum daily milk flow by the minimum and maximum percentages of fat.

The second, or lower part of each table, gives the kinds and amounts of the different feeding stuffs eaten *per day per 1,000 pounds live weight*, and the weights of the total and digestible nutrients (protein, fat and carbohydrates) which they furnished. As stated previously, all of the different feeding stuffs used in these rations were analysed, and from the results of these analyses the weights of the total nutrients furnished by the different coarse fodders and concentrated foods were obtained. The results of these analyses are given on pages 17-20 of this Report. The method employed in calculating the fuel value or potential energy furnished by the different foods, is referred to on page 17 of this Report.

The weights of digestible nutrients in the rations were obtained from the weights of total nutrients by the use of factors (coefficients of digestibility) obtained from the results of digestion experiments in this country and Germany. The following figures are taken from a paper* in which the results of nearly all American and other digestion experiments are summarized.

* Report of this Station for 1893, pp. 156-167.

Coefficients of Digestibility used in calculating the Digestible Nutrients in the Different Feeding Stuffs used in these Rations.

	Protein.	Fat.	Carbohydrates.	
			Nit.-free Ex.	Fiber.
	%	%	%	%
Wheat bran, - - - - -	78*	76*	72*	33†
Linseed meal, - - - - -	86†	90†	80†	50†
Cotton seed meal, - - - - -	89*	100*	68*	33†
Pea meal, - - - - -	83*	54*	94*	26*
Corn meal, - - - - -	76†	92*	87*	58†
Corn and cob meal, - - - - -	76*	82*	84*	28*
Gluten meal, - - - - -	87*	88*	91*	33†
Malt sprouts, - - - - -	81†	68†	76†	64†
Good quality hay, - - - - -	54*	54*	63*	55*
Poor quality hay, - - - - -	45*	28*	60*	46*
Rowen hay, - - - - -	62†	46†	67†	64†
Corn stalks (stover), - - - - -	52*	52*	64*	66*
Corn silage, - - - - -	46*	80*	67*	67*
Turnips, etc., - - - - -	84*	77*	95*	80*

* From results of American digestion experiments.

† From results of German digestion experiments.

In order to show the range of variation from day to day in the feeding of the same herd, the minimum and maximum daily rations per 1,000 pounds live weight are appended to these tables. The size of the rations is here measured by the fuel value of the digestible nutrients (protein, fat, etc.) A ration which has a large fuel value may have a small amount of a given kind of food or a given kind of nutrients. Hence it sometimes happens that the minimum of one of the nutrients furnished by a certain kind of feeding stuff in a given ration may be greater than the average of the nutrients in that ration. This is the case with the minimum of the coarse food in ration 23, table 8. The same may happen conversely, in the case of the maximum.

TABLE 3.

Dairy Test No. 18.—Statistics of Herd from Dec. 4 to 16, 1893.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	7	900	3	25.3	28.5	26.8	4.3	4.8	4.6	1.10	1.36	1.22
2	G. Jy.,	7	875	5	22.1	25.3	23.3	4.4	5.1	4.8	1.03	1.19	1.11
3	Gy., -	3	800	8	6.3	7.6	7.2	5.3	6.3	5.9	.34	.46	.42
4	Gy., -	6	775	4	21.4	26.6	23.0	3.9	4.7	4.3	.86	1.17	.98
5	Jy., -	6	825	4	19.5	25.7	22.4	4.3	5.0	4.7	.97	1.17	1.06
6	R. Gy.,	5	850	7	16.0	18.2	17.2	4.7	5.8	5.4	.75	.99	.92
7	R. Gy.,	4	850	5	20.2	22.5	21.4	4.8	5.4	5.1	.99	1.18	1.08
8	H.G. Jy.	5	800	4	10.8	12.3	11.6	5.6	6.2	5.9	.60	.74	.68
9	R. Ay.,	3	700	10	11.8	23.9	14.1	3.8	4.2	4.0	.46	.98	.57
10	G. Gy.,	6	950	9	12.4	13.8	13.2	4.7	5.3	5.0	.60	.71	.66
11	D & Gy.,	3	925	5	16.4	23.0	20.4	3.9	4.6	4.3	.67	.99	.87
12	R. Gy.,	10	850	8	6.9	13.3	9.1	4.8	6.4	5.5	.41	.64	.49
13	G. Gy.,	8	900	2	27.7	32.3	29.3	4.4	5.0	4.7	1.27	1.50	1.38
14	R. Gy.,	7	850	6	11.7	21.1	17.2	4.0	6.1	5.6	.47	1.29	.98
15	R. Gy.,	4	900	6	13.8	16.8	15.4	4.8	6.1	5.3	.71	1.02	.82
16	Jy., -	4	725	4	12.8	21.8	19.2	5.6	6.5	6.0	.73	1.42	1.16
17	Jy., -	4	700	3	13.5	20.5	18.1	3.9	5.6	4.3	.65	.91	.78
18	G. Gy.,	4	800	5	13.9	18.2	17.0	5.4	7.2	6.5	.75	1.24	1.11
19	Gy., -	2	750	3	13.2	16.6	14.4	4.3	5.7	5.1	.58	.88	.73

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Wheat bran, -	6.2	1.03	.32	3.46	.54	—	.80	.23	2.46	—	—
Corn meal, -	4.6	.47	.19	3.29	.05	—	.35	.18	2.88	—	—
Cotton seed meal,	1.5	.73	.14	.36	.06	—	.65	.14	.27	—	—
Total conc. food,	12.3	2.23	.65	7.11	.65	21300	1.80	.55	5.61	3.9	16100
Ensilage, -	12.1	.34	.15	2.39	.62	—	.16	.12	2.02	—	—
Hay, -	20.1	1.19	.61	8.92	5.81	—	.64	.33	8.82	—	—
Total coarse food,	32.2	1.53	.76	11.31	6.43	39050	.80	.45	10.84	15.0	23600
Total food, -	44.5	3.76	1.41	18.42	7.08	60350	2.60	1.00	16.45	7.3	39700
<i>Minimum per day.</i>											
Concentrated food,	12.6	2.23	.65	7.36	.67	21850	1.80	.55	5.81	4.0	16500
Coarse food, -	28.9	1.36	.67	9.99	5.61	34350	.71	.40	9.54	14.8	20750
Total, -	41.5	3.59	1.32	17.35	6.28	56200	2.51	.95	15.35	7.0	37250
<i>Maximum per day.</i>											
Concentrated food,	12.3	2.37	.65	7.03	.60	21350	1.94	.55	5.61	3.6	16350
Coarse food, -	36.8	1.75	.87	12.98	7.40	44850	.92	.52	12.44	14.9	27050
Total, -	49.1	4.12	1.52	20.1	8.00	66200	2.86	1.07	18.05	7.2	43400

TABLE 4.

Dairy Test No. 19.—Statistics of Herd from Dec. 18 to 30, 1893.

Ref. No.	BREED.	Age.	Weicht.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	7	825	2	17.4	20.7	19.6	4.7	5.6	5.2	.89	1.10	1.02
2	G. Jy.,	6	875	1	27.2	30.3	28.6	4.0	4.7	4.3	1.15	1.42	1.25
3	G. Jy.,	7	850	6	12.1	14.2	13.1	5.4	6.2	5.7	.65	.80	.75
4	G. Jy.,	7	900	1	17.0	19.3	18.2	3.9	4.5	4.2	.70	.85	.76
5	G. Dev.,	7	800	7	14.2	16.2	15.1	4.0	4.8	4.4	.60	.78	.67
6	G. Jy.,	9	825	4	15.4	18.8	16.9	4.4	5.2	4.9	.71	.92	.82
7	G. Jy.,	7	825	6	16.8	18.8	17.6	4.8	5.8	5.2	.84	1.01	.92
8	G. Jy.,	4	775	3	13.9	18.4	16.8	6.0	7.0	6.4	.89	1.15	1.07
9	G. Jy.,	10	950	30	13.3	19.2	15.3	5.8	7.4	6.8	.94	1.18	1.04
10	G. Jy.,	6	925	4	15.9	19.0	17.4	4.0	4.4	4.3	.70	.80	.74
11	G. Jy.,	4	800	5	12.9	16.8	15.1	4.8	5.5	5.2	.64	.89	.78
12	G. Jy.,	4	825	9	12.9	15.3	13.6	5.4	6.0	5.7	.70	.87	.78
13	G. Jy.,	5	750	1	15.9	18.4	17.5	4.3	5.3	4.7	.78	.87	.82
14	G. Jy.,	4	800	5	16.7	19.3	17.8	4.7	5.4	5.1	.83	.95	.90
15	G. Jy.,	4	775	4	16.1	19.4	17.4	4.6	5.1	4.9	.79	.97	.84

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit-free Exl.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Corn and rye meal,	3.8	.38	.12	2.58	.06	—	.29	.11	2.27	—	—
Gluten meal, -	3.3	1.31	.47	1.17	.05	—	1.14	.41	1.09	—	—
Bran, - -	3.6	.73	.21	1.80	.31	—	.57	.16	1.29	—	—
Total conc. food,	10.7	2.42	.80	5.55	.42	19000	2.00	.68	4.65	3.2	15200
Fodder, - -	18.9	1.32	.48	8.25	5.24	29550	.70	.25	8.48	13.0	18100
Total food, -	29.6	3.74	1.28	13.80	5.66	48550	2.70	.93	13.13	5.7	33300
<i>Minimum per day.</i>											
Concentrated food,	10.6	2.41	.80	5.50	.44	18900	1.98	.67	4.59	3.2	15050
Coarse food, -	17.0	1.19	.43	7.41	4.71	26600	.63	.23	7.61	13.0	16300
Total, - -	27.6	3.60	1.23	12.91	5.15	45500	2.61	.90	12.20	5.6	31350
<i>Maximum per day.</i>											
Concentrated food,	10.4	2.27	.76	5.53	.39	18450	1.87	.65	4.67	3.4	14900
Coarse food, -	22.1	1.55	.56	9.63	6.12	34550	.82	.30	9.89	13.0	21200
Total, - -	32.5	3.82	1.32	15.16	6.51	53000	2.69	.95	14.56	6.3	36100

TABLE 5.

Dairy Test No. 20.—Statistics of Herd from Jan. 2 to 13, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	5	800	3	20.4	24.5	22.4	3.4	4.0	3.6	.71	.90	.81
2	G. Jy.,	10	825	2	21.7	25.0	23.2	3.3	4.1	3.9	.76	.99	.90
3	G. Jy.,	3	675	5	11.2	13.0	11.9	4.1	4.9	4.6	.49	.59	.55
4	Native,	12	725	9	8.5	10.3	9.5	4.1	5.0	4.5	.35	.52	.42
5	Native,	7	725	4	16.8	19.6	17.9	3.7	4.8	4.0	.65	.86	.72
6	G. Jy.,	3	650	5	10.6	13.2	12.0	4.1	4.9	4.7	.48	.65	.56
7	G. Jy.,	4	825	4	19.8	22.4	21.2	3.6	4.2	4.0	.71	.90	.84
8	G. Jy.,	6	800	2	21.4	24.7	23.1	3.0	3.6	3.4	.65	.89	.78
9	Native,	5	850	3	18.9	22.0	20.4	4.2	4.9	4.6	.79	1.02	.94
10	Native,	12	900	1	19.9	25.0	23.5	3.6	4.5	4.1	.82	1.12	.95
11	Native,	12	825	1	22.9	28.4	25.5	3.4	4.3	3.8	.82	1.16	.97
12	Native,	13	800	2	18.0	24.0	19.6	3.2	3.6	3.4	.59	.86	.67
13	G. Jy.,	2	600	6	9.4	11.1	10.2	4.5	5.1	4.8	.45	.53	.49
14	G. Jy.,	5	800	2	17.1	20.3	18.9	3.9	4.9	4.5	.73	.97	.85
15	G. Jy.,	2	600	5	9.1	15.2	10.5	4.5	5.0	4.7	.43	.76	.50
16	G. Jy.,	2	600	5	10.1	15.7	11.5	4.9	5.5	5.1	.51	.83	.59

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Cob meal, - -	8.3	.94	.32	5.74	.37	—	.71	.26	4.92	—	—
Bran, - -	3.8	.65	.18	2.11	.33	—	.51	.13	1.50	—	—
Total conc. food,	12.1	1.59	.50	7.85	.70	20950	1.22	.39	6.42	6.1	15800
Fodder, - -	16.1	.89	.34	5.62	4.16	—	.40	.09	5.29	—	—
Oat hay, - -	8.4	.64	.28	3.54	2.10	—	.35	.16	3.38	—	—
Total coarse food,	24.5	1.53	.62	9.16	6.26	34150	.75	.25	8.67	12.4	18600
Total food, -	36.6	3.12	1.12	17.01	6.96	55100	1.97	.64	15.09	8.5	34400
<i>Minimum per day.</i>											
Concentrated food,	12.5	1.62	.52	8.11	.71	21600	1.24	.41	6.66	6.2	16400
Coarse food, -	20.2	1.28	.52	7.59	5.16	28300	.63	.22	7.19	12.3	15500
Total, - -	32.7	2.90	1.04	15.70	5.87	49900	1.87	.63	13.85	8.2	31900
<i>Maximum per day.</i>											
Concentrated food,	12.5	1.64	.52	8.08	.72	21600	1.26	.41	6.61	6.1	16400
Coarse food, -	28.9	1.78	.71	10.72	7.40	40000	.86	.28	10.14	12.6	21600
Total, - -	41.4	3.42	1.23	18.80	8.12	61600	2.12	.69	16.75	8.7	38000

TABLE 6.

Dairy Test No. 21.—Statistics of Herd from Jan. 15 to 27, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Dev.,	7	850	1	37.3	41.1	39.3	3.9	4.5	4.2	1.53	1.74	1.65
2	G. Jy.,	7	875	5	20.4	23.8	22.0	4.4	5.1	4.8	.98	1.16	1.06
3	G. Sw.,	6	925	1	30.4	33.6	31.8	4.2	4.7	4.5	1.29	1.58	1.42
4	Gy.,	6	775	4	14.2	23.5	21.4	4.1	4.5	4.3	.61	1.05	.92
5	Jy.,	6	825	4	17.4	21.6	19.6	4.2	5.0	4.6	.78	.99	.89
6	R. Gy.,	5	850	7	17.7	20.2	19.2	4.3	5.2	4.9	.87	1.01	.94
7	R. Gy.,	4	850	5	21.9	25.0	22.9	4.6	5.5	5.1	1.01	1.35	1.16
8	G. Jy.,	6	775	0	20.6	28.7	24.9	4.6	5.4	5.0	1.05	1.49	1.26
9	R. Ay.,	3	700	10	9.9	11.5	10.6	4.1	4.6	4.3	.41	.51	.45
10	Gy.,	20 m	700	2	11.5	13.8	12.3	4.0	4.7	4.3	.47	.59	.53
11	D & Gy.,	3	925	5	19.7	24.6	22.2	3.9	4.8	4.4	.92	1.02	.96
12	R. Gy.,	10	850	8	8.3	10.0	9.3	5.0	5.9	5.5	.45	.58	.51
13	G. Gy.,	8	900	2	25.0	28.5	26.7	4.3	5.0	4.6	1.10	1.34	1.23
14	R. Gy.,	7	850	6	16.9	19.2	18.2	5.0	5.6	5.2	.87	1.05	.95
15	R. Gy.,	4	900	6	13.4	16.9	14.8	4.8	5.5	5.1	.69	.86	.75
16	Jy.,	4	725	4	18.5	22.4	20.2	5.7	6.5	6.1	1.11	1.34	1.23
17	Jy.,	4	700	3	21.6	25.2	23.1	3.3	4.5	3.9	.72	1.00	.91
18	G. Gy.,	4	800	5	14.4	19.9	17.4	5.6	6.8	6.3	.92	1.35	1.09
19	G. Gy.,	2	750	3	14.6	16.8	15.5	5.1	5.7	5.3	.74	.91	.82

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Grain, - -	12.5	2.74	.72	6.65	.72	21850	2.19	.59	5.15	3.0	16100
Hay, - -	9.7	.57	.29	4.29	2.80	—	.31	.16	4.24	—	—
Ensilage, - -	15.3	.43	.20	3.02	.79	—	.20	.16	2.55	—	—
Oat hay, - -	4.9	.38	.14	2.13	1.37	—	.20	.08	2.09	—	—
Total coarse food,	29.9	1.38	.63	9.44	4.06	32000	.71	.40	8.88	13.9	19500
Total food, -	42.4	4.12	1.35	16.09	5.68	53850	2.90	.99	14.03	5.7	35600
<i>Minimum per day.</i>											
Concentrated food,	11.0	2.41	.63	5.85	.63	19200	1.93	.52	4.53	3.0	14200
Coarse food, -	31.4	1.42	.64	9.70	5.00	32700	.73	.41	9.08	13.8	20000
Total, - -	42.4	3.83	1.27	15.55	5.63	51900	2.66	.93	13.61	6.0	34200
<i>Maximum per day.</i>											
Concentrated food,	13.3	2.91	.76	7.07	.77	23200	2.33	.63	5.47	3.0	17200
Coarse food, -	29.7	1.37	.62	9.34	4.89	31650	.70	.39	8.77	13.9	19200
Total, - -	43.0	4.28	1.38	16.41	5.66	54850	3.03	1.02	14.24	5.5	36400

TABLE 7.

Dairy Test No. 22.—Statistics of Herd from Jan. 29 to Feb. 10, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	Native,	11	875	2	16.4	19.0	17.7	4.5	4.9	4.7	.79	.89	.83
2	G. Dur.,	8	900	2	17.0	19.7	18.3	3.4	3.9	3.7	.58	.77	.67
3	G. Dur.,	7	900	2	21.1	23.8	22.7	3.5	4.0	3.8	.80	.95	.86
4	G. Jy.,	9	750	4	14.2	17.1	15.8	3.5	3.9	3.8	.53	.67	.60
5	Native,	5	600	1	18.1	21.6	20.3	3.4	4.0	3.6	.66	.79	.74
6	G. Jy.,	4	750	1	17.4	19.9	18.7	3.0	3.6	3.3	.53	.72	.62
7	G. Jy.,	3	600	9	7.5	11.2	8.8	3.6	4.0	3.8	.29	.41	.34
8	G. Jy.,	9	725	4	15.4	17.3	16.0	4.0	4.8	4.3	.63	.74	.69
9	Native,	3	600	9	8.6	9.6	9.0	4.3	5.0	4.7	.38	.46	.42
10	G. Jy.,	10	850	12	8.1	9.6	9.2	3.9	4.8	4.1	.33	.42	.38
11	G. Gy.,	4	800	8	5.9	8.0	6.9	4.3	4.8	4.6	.27	.37	.32
12	Native,	3	700	9	9.6	12.3	11.0	3.6	4.1	3.9	.36	.48	.42
13	Native,	3	825	9	9.0	15.1	13.5	3.6	4.3	3.9	.39	.61	.53
14	Native,	3	650	11	8.5	10.5	9.2	4.8	5.4	5.1	.42	.53	.47
15	G. Jy.,	4	625	11	2.5	7.4	6.4	5.2	5.9	5.5	.15	.40	.35
16	G. Jy.,	3	575	11	4.2	5.9	5.0	4.2	5.0	4.6	.18	.28	.23

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Cob meal, -	5.9	.58	.18	4.07	.26	—	.44	.15	3.49	—	—
Wheat bran, -	4.1	.80	.19	2.18	.35	—	.62	.14	1.56	—	—
Total conc. food,	10.0	1.38	.37	6.25	.61	16900	1.06	.29	5.05	5.4	12600
Stover, -	4.8	.48	.11	2.49	1.06	—	.25	.06	2.29	—	—
Oat hay, -	5.4	.58	.19	2.33	1.67	—	.31	.10	2.39	—	—
Hay, -	6.2	.54	.21	2.95	1.65	—	.29	.11	2.78	—	—
Total coarse food,	16.4	1.60	.51	7.77	4.41	27800	.85	.27	7.46	9.6	16600
Total food, -	26.4	2.98	.88	14.02	5.02	44700	1.91	.56	12.51	7.3	29200
<i>Minimum per day.</i>											
Concentrated food,	9.8	1.36	.37	6.08	.62	16550	1.05	.29	4.92	5.4	12300
Coarse food, -	13.4	1.33	.47	6.04	3.91	22950	.72	.25	5.96	9.2	13500
Total, -	23.2	2.69	.84	12.12	4.53	39500	1.77	.54	10.88	6.9	25800
<i>Maximum per day.</i>											
Concentrated food,	10.2	1.42	.38	6.33	.65	17250	1.10	.30	5.12	5.3	12850
Coarse food, -	18.1	1.70	.51	9.01	4.41	30250	.90	.27	8.39	10.1	18400
Total, -	28.3	3.12	.89	15.34	5.06	47500	2.00	.57	13.51	7.5	31250

TABLE 8.

Dairy Test No. 23.—Statistics of Herd from Feb. 12 to 24, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	5	800	3	19.5	23.2	21.3	3.6	4.1	3.9	.78	.90	.82
2	G. Jy.,	10	825	2	22.3	24.8	24.0	3.7	4.1	3.9	.89	1.01	.94
3	G. Jy.,	3	675	5	11.4	13.8	12.2	4.6	5.2	4.8	.53	.65	.59
4	G. Jy.,	3	750	1	21.2	23.9	22.4	3.7	4.6	4.0	.80	1.07	.89
5	Native,	7	725	4	15.8	17.5	16.6	3.7	4.2	3.9	.58	.69	.64
6	G. Jy.,	3	650	5	12.1	13.9	13.0	4.8	5.2	5.1	.62	.70	.67
7	G. Jy.,	4	825	4	20.8	23.0	22.0	3.8	4.4	4.1	.85	.97	.90
8	G. Jy.,	6	800	2	21.1	23.4	22.3	3.4	3.7	3.5	.72	.85	.78
9	Native,	5	850	3	18.8	23.3	20.3	4.4	4.9	4.7	.88	1.03	.95
10	Native,	12	900	1	18.3	23.2	20.0	4.0	4.6	4.3	.75	1.06	.86
11	Native,	12	825	1	20.6	23.3	22.1	3.3	3.9	3.7	.72	.87	.81
12	Native,	13	800	2	19.3	22.3	20.3	3.4	3.7	3.5	.66	.80	.71
13	G. Jy.,	2	600	6	11.0	14.4	12.2	4.5	5.3	4.9	.53	.72	.59
14	G. Gy.,	5	800	2	16.2	19.1	18.0	4.1	4.9	4.5	.73	.89	.81
15	G. Jy.,	2	600	5	10.5	12.3	10.8	4.4	4.8	4.6	.47	.59	.50
16	G. Jy.,	2	600	5	12.4	15.0	13.5	4.9	7.5	5.7	.61	1.10	.77

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Corn and cob meal,	3.3	.36	.12	2.18	.17	—	.27	.10	1.88	—	—
Bran, - -	5.4	.99	.29	2.88	.50	—	.77	.21	2.06	—	—
Gluten meal, -	3.1	1.06	.12	1.56	.06	—	.92	.11	1.44	—	—
Total conc. food,	11.8	2.41	.53	6.62	.73	20400	1.96	.42	5.38	3.3	15400
Fodder, - -	13.6	.75	.28	4.76	3.52	—	.34	.07	4.47	—	—
Oat hay, - -	9.2	.70	.31	3.87	2.30	—	.38	.17	3.70	—	—
Total coarse food,	22.8	1.45	.59	8.63	5.82	32050	.72	.24	8.17	12.2	17550
Total food, -	34.6	3.86	1.12	15.25	6.55	52450	2.68	.66	13.55	5.7	32950
<i>Minimum per day.</i>											
Concentrated food,	10.8	2.20	.48	6.05	.67	18600	1.80	.38	4.91	3.3	14100
Coarse food, -	23.2	1.48	.60	8.77	5.92	32600	.73	.25	8.31	12.2	17850
Total, - -	34.0	3.68	1.08	14.82	6.59	51200	2.53	.63	13.22	5.8	31950
<i>Maximum per day.</i>											
Concentrated food,	11.8	2.41	.53	6.61	.73	20350	1.97	.42	5.36	3.3	15400
Coarse food, -	24.0	1.53	.61	9.07	6.12	33700	.75	.25	8.58	12.3	18400
Total, - -	35.8	3.94	1.14	15.68	6.85	54050	2.72	.67	13.94	5.8	33800

TABLE 9.

Dairy Test No. 24.—Statistics of Herd from Feb. 26 to March 3, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	P. Jy.,	3	750	4	20.1	21.6	20.9	3.8	4.0	3.9	.76	.83	.81
2	G. Jy.,	3	650	10	16.4	17.8	17.1	5.0	5.1	5.1	.84	.89	.87
3	P. Jy.,	5	775	6	16.6	17.0	16.8	5.0	5.4	5.2	.85	.92	.88
4	G. Jy.,	6	800	0	23.2	26.2	24.8	3.2	3.6	3.4	.74	.89	.84
5	Native,	10	725	11	13.8	14.7	14.2	5.4	5.7	5.5	.77	.80	.79
6	G. Dev.,	6	800	2	22.8	24.1	23.5	3.2	3.9	3.6	.75	.92	.84
7	G. Jy.,	9	800	2	20.2	22.5	21.0	4.4	4.7	4.6	.93	1.04	.96
8	G. Jy.,	7	825	6	16.3	18.9	17.6	4.6	5.0	4.9	.81	.95	.87
9	G. Jy.,	5	800	4	12.0	13.6	12.9	4.4	4.8	4.6	.54	.65	.60
10	G. Jy.,	4	850	5	14.9	16.7	15.7	5.0	5.3	5.2	.77	.84	.81
11	P. Gy.,	3	775	1	23.6	25.6	25.0	4.7	5.0	4.9	1.13	1.28	1.21
12	G. Jy.,	12	800	2	24.6	27.1	25.9	3.2	3.4	3.3	.84	.89	.86
13	G. Jy.,	5	750	2	16.2	19.0	17.7	4.9	5.0	4.9	.79	.93	.87
14	G. Jy.,	3	750	1	24.8	25.8	25.3	4.3	4.4	4.4	1.07	1.13	1.11

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit-free Exl.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Grain, - -	13.6	2.49	.62	7.78	.56	22750	1.97	.51	6.54	4.0	18000
Stover, - -	3.4	.27	.06	1.43	.92	—	.16	.04	1.63	—	—
Clover hay, -	8.3	1.78	.31	2.82	1.88	—	1.08	.15	2.69	—	—
Hay, - - -	8.7	.51	.22	4.00	2.62	—	.27	.12	3.96	—	—
Total coarse food,	20.4	2.56	.59	8.25	5.42	32700	1.51	.31	8.28	6.0	19500
Total food, -	34.0	5.05	1.21	16.03	5.98	55450	3.48	.82	14.82	4.8	37500
<i>Minimum per day.</i>											
Concentrated food,	13.6	2.49	.62	7.79	.56	22800	1.97	.51	6.55	4.0	18000
Coarse food, -	19.8	2.46	.60	8.14	5.36	32200	1.44	.30	7.95	6.0	18700
Total, - - -	33.4	4.95	1.22	15.93	5.92	55000	3.41	.81	14.50	4.8	36700
<i>Maximum per day.</i>											
Concentrated food,	13.8	2.53	.63	7.90	.57	23100	2.00	.51	6.65	4.0	18300
Coarse food, -	20.6	2.71	.58	8.08	5.29	32350	1.61	.32	8.43	5.7	20000
Total, - - -	34.4	5.24	1.21	15.98	5.86	55450	3.61	.83	15.08	4.8	38300

TABLE 10.

Dairy Test No. 25.—Statistics of Herd from March 5 to 17, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	Native,	11	875	2	16.3	18.9	17.6	4.8	5.8	5.1	.82	.98	.91
2	G. Dur.,	8	900	2	17.7	20.1	18.8	3.7	4.1	3.9	.67	.82	.74
3	G. Dur.,	7	900	2	21.0	24.3	22.6	4.0	4.3	4.1	.86	1.00	.93
4	G. Jy.,	9	750	4	15.2	18.8	17.0	3.6	4.0	3.8	.55	.71	.65
5	Native,	5	600	1	19.2	23.2	21.3	3.5	3.9	3.7	.73	.84	.78
6	G. Jy.,	4	750	1	16.2	18.7	18.0	3.9	4.4	4.1	.69	.78	.73
7	G. Jy.,	3	600	9	9.1	11.2	10.3	3.9	4.3	4.1	.36	.46	.42
8	G. Jy.,	9	725	4	15.1	17.9	16.7	4.2	4.7	4.4	.67	.81	.73
9	Native,	3	600	9	9.2	11.1	10.2	4.8	5.3	5.0	.45	.55	.51
12	Native,	3	700	9	10.2	12.8	11.6	3.8	4.5	4.1	.44	.54	.48
13	Native,	3	825	9	15.0	17.9	16.3	3.9	4.3	4.0	.59	.73	.66
14	Native,	3	650	11	9.4	11.9	10.6	5.0	5.7	5.4	.49	.66	.57

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
Grain, - -	10.8	2.03	.49	6.14	.66	18500	1.60	.40	5.06	3.8	14100
Oat hay, - -	8.1	.87	.28	3.50	2.51	—	.47	.15	3.59	—	—
Hay, - -	8.7	.76	.30	4.13	2.35	—	.41	.16	3.89	—	—
Total coarse food,	16.8	1.63	.58	7.63	4.86	28700	.88	.31	7.48	9.4	16800
Total food, -	27.6	3.66	1.07	13.77	5.52	47200	2.48	.71	12.54	5.8	30900
<i>Minimum per day.</i>											
Concentrated food,	10.0	1.87	.45	5.66	.62	17050	1.48	.37	4.66	3.8	13000
Coarse food, -	16.1	1.57	.55	7.31	4.68	27550	.84	.30	7.19	9.4	16200
Total, - -	26.1	3.44	1.00	12.97	5.30	44600	2.32	.67	11.85	5.8	29200
<i>Maximum per day.</i>											
Concentrated food,	11.4	2.13	.52	6.46	.70	19450	1.68	.43	5.32	3.8	14800
Coarse food, -	17.6	1.71	.61	8.00	5.09	30100	.93	.33	7.84	9.3	17700
Total, - -	29.0	3.84	1.13	14.46	5.79	49550	2.61	.76	13.16	5.8	32500

TABLE II.

Dairy Test No. 26.—Statistics of Herd from March 19 to 24, 1894.

Ref. No.	BREED.	Age.	Weight.	Mos. Since Last Calf.	DAILY MILK FLOW.			DAILY PERCENT-AGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy.,	8	800	4	13.7	14.8	14.4	5.2	5.3	5.2	.73	.77	.75
2	G. Hol.,	12	850	17	11.6	14.2	12.8	4.9	5.6	5.2	.61	.71	.66
3	Native,	8	900	16	10.5	12.4	11.1	4.7	4.9	4.8	.49	.60	.53
4	G. Jy.,	11	825	9	13.6	16.1	14.8	5.3	5.8	5.5	.72	.89	.82
5	G. Jy.,	12	850	15	14.6	15.6	15.0	5.5	6.2	5.8	.82	.93	.88
6	Native,	11	800	9	15.4	16.3	15.9	5.1	5.7	5.4	.83	.91	.86
7	G. Jy.,	8	850	21	7.8	9.0	8.6	4.8	5.0	4.9	.39	.43	.42
8	Native,	9	950	19	13.8	16.1	14.7	4.4	4.8	4.5	.63	.71	.67
9	Native,	4	850	19	7.7	8.8	8.4	5.7	6.5	6.2	.48	.55	.52
10	G. Jy.,	4	750	1	22.4	25.0	23.6	3.1	3.9	3.6	.69	.89	.84
11	G. Jy.,	4	825	7	12.5	13.3	12.9	5.4	5.8	5.6	.68	.77	.72
12	G. Jy.,	5	800	1	20.1	27.6	24.6	3.4	3.6	3.5	.68	.99	.86
13	G. Jy.,	3	700	9	6.3	7.7	7.2	6.5	6.8	6.6	.41	.50	.48
14	G. Jy.,	3	675	11	5.8	6.4	6.1	6.1	6.8	6.4	.36	.43	.39
15	G. Jy.,	3	700	12	6.4	8.3	7.2	5.8	8.1	6.8	.38	.67	.50

Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.

KINDS OF FEED.	Average Fed per Day.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.
Gluten meal, -	3.5	.92	.55	1.45	.36	—	.80	.48	1.44	—	—
Middlings, -	7.1	1.48	.46	3.53	.56	—	1.15	.35	2.72	—	—
Total conc. food,	10.6	2.40	1.01	4.98	.92	19700	1.95	.83	4.16	3.2	14900
Hay, -	14.3	1.05	.40	6.46	4.06	23200	.57	.22	6.31	12.1	13700
Total food, -	24.9	3.45	1.41	11.44	4.98	42900	2.52	1.05	10.47	5.2	28600
<i>Minimum per day.</i>											
Concentrated food,	11.0	2.49	1.04	5.19	.97	20450	2.03	.85	4.34	3.1	15400
Coarse food, -	10.0	.73	.28	4.52	2.85	16250	.39	.15	4.42	12.3	9600
Total, -	21.0	3.22	1.32	9.71	3.82	36700	2.42	1.00	8.76	4.7	25000
<i>Maximum per day.</i>											
Concentrated food,	10.8	2.45	1.04	5.08	.94	20150	1.99	.86	4.26	3.2	15200
Coarse food, -	15.2	1.11	.43	6.88	4.32	24700	.60	.23	6.71	12.1	14600
Total, -	26.0	.56	1.47	11.96	5.26	44850	2.59	1.09	10.97	5.4	29800

TABLE 12.

*Summary of Total and Digestible Nutrients Fed per Day per 1,000
Lbs., Live Weight, on Dairy Farms in Connecticut.*

Reference No.	CLASSES OF FOOD.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Ash.	Nit-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo- hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
1	Concentrated food,	1.87	.64	4.00	.65	14800	1.58	.55	3.51	—	11790
	Coarse food, -	1.80	.70	9.61	6.17	35700	.93	.44	9.73	—	21660
	Total food, -	3.67	1.34	13.61	6.82	50500	2.51	.99	13.24	6.2	33450
2	Concentrated food,	2.51	.56	6.22	.70	19900	2.05	.49	5.58	—	16300
	Coarse food, -	1.49	.57	9.17	6.00	33400	.74	.36	9.61	—	20700
	Total food, -	4.00	1.13	15.39	6.70	53300	2.79	.85	15.19	6.1	37000
3	Concentrated food,	2.71	.96	5.11	.63	19700	2.39	.87	4.65	—	16770
	Coarse food, -	1.20	.54	10.10	5.64	33800	.62	.28	10.13	—	21180
	Total food, -	3.91	1.50	15.21	6.27	53500	3.01	1.15	14.78	5.7	37950
4	Concentrated food,	1.81	.55	6.27	.54	18300	1.47	.46	4.99	—	14000
	Coarse food, -	2.14	.86	11.94	7.06	43000	1.15	.47	11.67	—	25800
	Total food, -	3.95	1.41	18.21	7.60	61300	2.62	.93	16.66	7.0	39800
5	Concentrated food,	2.64	.88	3.39	.31	15500	2.20	.76	2.64	—	12200
	Coarse food, -	1.90	.73	12.43	7.31	43300	.96	.49	12.55	—	27200
	Total food, -	4.54	1.61	15.82	7.62	58800	3.16	1.25	15.19	5.7	39400
6	Concentrated food,	1.56	.54	4.19	.20	13400	1.23	.51	3.58	—	11100
	Coarse food, -	1.49	.67	11.04	6.90	38900	.80	.36	10.97	—	23400
	Total food, -	3.05	1.21	15.23	7.10	52300	2.03	.87	14.55	8.1	34500
7	Concentrated food,	1.97	.74	8.96	.51	24400	1.44	.65	7.70	—	19740
	Coarse food, -	1.86	.81	11.23	5.87	38700	1.00	.44	10.30	—	22860
	Total food, -	3.83	1.55	20.19	6.38	63100	2.44	1.09	18.00	8.4	42600
8	Concentrated food,	2.08	.64	6.47	1.23	20900	1.60	.50	5.35	—	15050
	Coarse food, -	2.98	.79	11.75	7.74	45100	1.56	.43	11.60	—	26300
	Total food, -	5.06	1.43	18.22	8.97	66000	3.16	.93	16.95	6.0	41350
9	Concentrated food,	1.62	.65	3.81	.22	13240	1.20	.58	3.14	—	10500
	Coarse food, -	1.68	.49	8.68	5.62	31760	.96	.25	8.91	—	19450
	Total food, -	3.30	1.14	12.49	5.84	45000	2.16	.83	12.05	6.4	29950

TABLE 12.—(Continued.)

Reference No.	CLASSES OF FOOD.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo- hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
10	Concentrated food,	1.57	.55	4.62	.27	14300	1.09	.50	3.72	—	11100
	Coarse food, -	2.11	.67	9.16	5.47	34000	1.23	.34	9.32	—	21000
	Total food, -	3.68	1.22	13.78	5.74	48300	2.32	.84	13.04	6.4	32100
11	Concentrated food,	2.51	.78	5.20	.43	18400	1.91	.70	4.17	—	14250
	Coarse food, -	1.58	.57	8.98	6.35	33900	.85	.31	9.29	—	20200
	Total food, -	4.09	1.35	14.18	6.78	52300	2.76	1.01	13.46	5.7	34450
12	Concentrated food,	2.96	.66	6.40	1.03	22100	2.29	.56	4.84	—	15650
	Coarse food, -	1.40	.57	6.38	3.95	24200	.70	.38	6.57	—	15100
	Total food, -	4.36	1.23	12.78	4.98	46300	2.99	.94	11.41	4.5	30750
13	Concentrated food,	2.25	.72	6.13	.56	19600	1.67	.64	5.27	—	15600
	Coarse food, -	1.03	.42	5.97	3.38	21100	.53	.28	5.90	—	13150
	Total food, -	3.28	1.14	12.10	3.94	40700	2.20	.92	11.17	6.0	28750
14	Concentrated food,	2.23	.85	4.95	.38	17690	1.71	.64	3.79	—	12900
	Coarse food, -	1.77	.76	9.77	5.47	34810	.95	.41	9.30	—	20850
	Total food, -	4.00	1.61	14.72	5.85	52500	2.66	1.05	13.09	5.8	33750
15	Concentrated food,	.92	.46	5.82	.28	15000	.70	.37	4.79	—	11800
	Coarse food, -	1.21	.36	9.24	5.55	31300	.65	.19	9.20	—	19100
	Total food, -	2.13	.82	15.06	5.83	46300	1.35	.56	13.99	11.3	30900
16	Concentrated food,	.82	.53	4.33	.28	12340	.61	.46	3.74	—	10100
	Coarse food, -	1.54	.63	9.56	5.10	32760	.83	.34	8.92	—	19500
	Total food, -	2.36	1.16	13.89	5.38	45100	1.44	.80	12.66	9.3	29600
18	Concentrated food,	2.23	.65	7.11	.65	21300	1.80	.55	5.61	3.9	16100
	Coarse food, -	1.53	.76	11.31	6.43	39050	.80	.45	10.84	15.0	23600
	Total food, -	3.76	1.41	18.42	7.08	60350	2.60	1.00	16.45	7.3	39700
19	Concentrated food,	2.42	.80	5.55	.42	19000	2.00	.68	4.65	3.2	15200
	Coarse food, -	1.32	.48	8.25	5.24	29550	.70	.25	8.48	13.0	18100
	Total food, -	3.74	1.28	13.80	5.66	48550	2.70	.93	13.13	5.7	33300
20	Concentrated food,	1.59	.50	7.85	.70	20950	1.22	.39	6.42	6.1	15800
	Coarse food, -	1.53	.62	9.16	6.26	34150	.75	.25	8.67	12.4	18600
	Total food, -	3.12	1.12	17.01	6.96	55100	1.97	.64	15.09	8.5	34400

TABLE 12.—(Continued.)

Reference No.	CLASSES OF FOOD.	TOTAL NUTRIENTS AND FUEL VALUE.					DIGESTIBLE NUTRIENTS AND FUEL VALUE.				
		Protein.	Fat.	Nit-free Ext.	Fiber.	Fuel Value.	Protein.	Fat.	Carbo- hydrates.	Nutritive Ratio.	Fuel Value.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.	Lbs.	1:	Cal.
21	Concentrated food,	2.74	.72	6.65	.72	21850	2.19	.59	5.15	3.0	16100
	Coarse food, -	1.38	.63	9.44	4.96	32000	.71	.40	8.88	13.9	19500
	Total food, -	4.12	1.35	16.09	5.68	53850	2.90	.99	14.03	5.7	35600
22	Concentrated food,	1.38	.37	6.25	.61	16900	1.06	.29	5.05	5.4	12600
	Coarse food, -	1.60	.51	7.77	4.41	27800	.85	.27	7.46	9.6	16600
	Total food, -	2.98	.88	14.02	5.02	44700	1.91	.56	12.51	7.3	29200
23	Concentrated food,	2.41	.53	6.62	.73	20400	1.96	.42	5.38	3.3	15400
	Coarse food, -	1.45	.59	8.63	5.82	32050	.72	.24	8.17	12.2	17550
	Total food, -	3.86	1.12	15.25	6.55	52450	2.68	.66	13.55	5.7	32950
24	Concentrated food,	2.49	.62	7.78	.56	22750	1.97	.51	6.54	4.0	18000
	Coarse food, -	2.56	.59	8.25	5.42	32700	1.51	.31	8.28	6.0	19500
	Total food, -	5.05	1.21	16.03	5.98	55450	3.48	.82	14.82	4.8	37500
25	Concentrated food,	2.03	.49	6.14	.66	18500	1.60	.40	5.06	3.8	14100
	Coarse food, -	1.63	.58	7.63	4.86	28700	.88	.31	7.48	9.4	16800
	Total food, -	3.66	1.07	13.77	5.52	47200	2.48	.71	12.54	5.8	30900
26	Concentrated food,	2.40	1.01	4.98	.92	19700	1.95	.83	4.16	3.2	14900
	Coarse food, -	1.05	.40	6.46	4.06	23200	.57	.22	6.31	12.1	13700
	Total food, -	3.45	1.41	11.44	4.98	42900	2.52	1.05	10.47	5.2	28600
<i>Average of the above 25 rations.</i>											
	Concentrated food, -	-	-	-	-	-	1.63	.55	4.78	3.6	14250
	Coarse food, -	-	-	-	-	-	.88	.35	9.14	11.3	20100
	Total food, -	-	-	-	-	-	2.51	.90	13.92	6.3	34350
<i>Average of 22 of the above rations.*</i>											
	Concentrated food, -	-	-	-	-	-	1.59	.56	4.72	3.1	14050
	Coarse food, -	-	-	-	-	-	.89	.35	9.23	11.3	20200
	Total food, -	-	-	-	-	-	2.48	.91	13.95	6.4	34250

* Three of the 25 rations (Nos. 21, 23 and 25) were suggested by the authors. Hence the 22 rations, the average of which is here given, actually represent the feeding practices of these dairymen.

Table 12, on pages 40 to 42, gives a summary of twenty-five rations fed on dairy farms in Connecticut. In the first five columns are given the total nutrients and the total fuel value in the materials fed. The three following columns give the calculated weights of digestible protein, fats and carbohydrates. As explained on page 30, these weights are calculated from the total nutrients by the use of factors (digestion coefficients) obtained from digestion experiments. These factors are only approximate, and the weights of nutrients obtained by their use are also approximate. The next column contains the nutritive ratio and the last column gives the fuel value of the digestible nutrients in the rations.

It will be seen from table 12 that the smallest weight of digestible protein fed per day per 1,000 pounds live weight, was 1.35 pounds, and the largest amount was 3.48 pounds. The fuel value of the digestible nutrients fed per 1,000 pounds live weight, varied from a minimum of 28,600 Calories to a maximum of 42,600 Calories. There was also a correspondingly large range in the nutritive ratio of the rations fed. The narrowest ration had the ratio of 1:4.5; the widest, of 1:11.3.

EXPLANATIONS.

Uses of food.—The two chief uses of food are to form the materials of the body and make up its wastes, and to yield energy in the form of heat to keep the body warm and in the form of muscular and other power for the work it has to do. The principal tissue-formers of the food are the protein or nitrogenous compounds. They build up and repair the nitrogenous materials, as the muscle and bone, and supply the albuminoids of blood, milk, and other fluids. The chief fuel ingredients of the food are the carbohydrates (such as sugar, starch, etc.,) and fat. These are either consumed in the body or stored as fat to be used as occasion demands.

Fuel value.—The value of food as fuel may be measured in terms of potential energy. The unit commonly used is the Calorie. One Calorie is the amount of heat necessary to raise the temperature of a pound of water about four degrees Fahrenheit.* From experiment it has been found that a pound of protein or carbohydrates yields, when burned, about 1,860 Calories of fuel value and that a pound of fat yields about 4,220 Calories.

*The Calorie is exactly the heat necessary to raise the temperature of 1 kilogram of water one degree Centigrade.

Nutritive ratio.—There is a very important relation between the amounts of protein (flesh formers) and the amounts of fuel constituents of a food. This relation is expressed by the nutritive ratio. The fuel value of fat is about two and one-fourth times that of the carbohydrates and the protein, hence it happens that if the sum of the digestible carbohydrates and two and one-fourth times the digestible fat of a ration is divided by the amount of digestible protein in the ration, the quotient gives what is called the nutritive ratio.

Wide ration.—*Narrow ration.*—If the quantities of digestible fat and carbohydrates are large relative to the protein, the nutritive ratio will be a large number and the ration is called a “wide ration;” if the quantities of digestible fat and carbohydrates are relatively small, the quotient is a small number and the ration is a “narrow” one. A ration where the nutritive ratio is much more than 1:6 may be called a “wide ration;” if much less it may be called a “narrow ration.”

Nearly all of the grasses and hays have a large nutritive ratio, and the same is true of corn and many of its products, such as meal and hominy chops. The use of such feeding stuffs will tend to make a ration wide. The legumes such as clover, peas, vetch, etc., and many of the products of milling and food manufacture are relatively rich in protein, and hence have small nutritive ratios. Wide rations are much more common among American feeders than are narrow ones. Narrow rations would be better. Practically it is probably unwise to feed a ration whose nutritive ratio is greater than that of one to six or seven.

The measure of the size of a ration.—In order that a ration may be complete, there must be enough digestible protein supplied in the food to build new tissues (bone, muscle, milk, etc.,) and repair the wastes of the body, and sufficient digestible fat and carbohydrates to furnish heat and muscular energy. As the chief function of the fat and carbohydrates is to serve as fuel, it is more important that enough of these should be provided to meet the needs of the animal than that they should be supplied in definite relative proportions. It is, therefore, possible to form a very good idea of the nutrients furnished in a ration, and to measure its size by the quantity of digestible protein or flesh-formers which it contains, and the fuel value of its digestible constituents.

DISCUSSION OF THE RESULTS OF THE TESTS.

The results brought out in such a study as the one here reported are tentative rather than final. This investigation was not undertaken with the expectation of obtaining startling facts, nor would we be warranted in drawing very definite conclusions from the tests. We do believe, however, that there is much of practical importance to be obtained along this line of inquiry, and that the results herewith presented merit the careful attention of dairymen.

It is probably true that the animals of most of the herds examined were, so far as breed, milk and butter product are concerned, above the average of cows kept for dairy purposes in Connecticut. It is doubtless true that the feeding practiced by the owners of these herds is better than that which is generally practiced throughout the State. These facts, taken together with the shortness of the periods of observation to which the herds were subjected, have been kept in mind in the following discussion of the results of the tests, which is reprinted from Bulletin 13 of this Station.

A RATION FOR A MILCH COW.

A proper daily ration will supply, in appropriate forms, the protein needed to form the nitrogenous materials of the body and the energy required for heat and muscular work, and a proper feeding standard will call for sufficient digestible protein, fats, and carbohydrates per day to meet these needs. But just what these weights should be is a matter of considerable uncertainty. Differences in breed and individual peculiarities of the animals, and in the food and handling, as well as other conditions, known and unknown, bring it about that the best rations for one cow may not be the best for another. The feeder must know his cows and fit the food to their wants. But in so doing he may be greatly helped by feeding standards.

In the following table are given the commonly quoted standard ration proposed twenty-five or more years ago by Prof. Wolff, an eminent German chemist and experimenter; the average of 128 American rations as ascertained by the Wisconsin Experiment Station; the average of 16 rations fed in Connecticut in 1893, and of 25 fed in 1893 and 1894; and a tentatively suggested ration.

*German (Wolff's) Standard Ration, together with Averages of
Some American Rations and a Tentatively Suggested
Ration per 1,000 Lbs., Live Weight.*

RATION.	Organic Matter.	DIGESTIBLE NUTRIENTS.				Nutritive Ratio.
		Pro- tein.	Fat.	Carbo- hydrates.	Fuel Value.	
	Lbs.	Lbs.	Lbs.	Lbs.	Calories.	1:
Wolff's (German) Stand- ard, - - - -	24.0	2.50	.40	12.50	29,600	5.4
Average of 128 American rations compiled by the Wisconsin Experiment Station,* - - -	24.5	2.15	.74	13.27	31,250	6.9
Average of 16 rations as fed in Connecticut in 1892-93, - - -	26.4	2.48	.94	14.09	34,800	6.5
Average of 25 rations as fed in Connecticut in 1892-94, - - -	26.8	2.51	.90	13.92	34,350	6.3
Tentatively suggested ra- tion, - - - -	25.0	2.50	(.5 to .8)†	(13 to 12)†	31,000†	5.6

* Wisconsin Experiment Station, Bulletin 38.

† In this suggested ration the fuel value could be supplied by about .5 of a pound of digestible fat and 13.0 pounds digestible carbohydrates; by .6 of a pound of digestible fat and 12.5 pounds of digestible carbohydrates; or by .8 of a pound of digestible fat and 12 pounds of digestible carbohydrates.

The German figures in the above table are based upon observations of the feeding practices of the best German feeders, and a large number of feeding experiments conducted by trained specialists, chiefly in experiment stations.

The 128 rations compiled by the Wisconsin Experiment Station were obtained in response to letters sent to "dairy farmers and breeders of dairy stock in all parts of the United States and Canada, asking information concerning their methods of feeding milch cows." The average of these rations represents the average of the feeding practice of American dairymen as ascertained from the more or less accurate estimates of the feeders themselves as to amounts fed, etc. The materials fed were not analyzed, but their composition was assumed from the averages of other analyses. The Wisconsin Station proposes* this average as an "American standard ration for dairy cows."

The Connecticut rations given in the table represent the actual feeding practices of the dairymen whose herds were examined, so far as could be learned by weighing the foods actually fed

* Wisconsin Agricultural Experiment Station, Bulletin 38, p. 46.

from day to day, and by determining their composition by chemical analysis. The factors used for calculating the quantities of digestible nutrients are the chief sources of uncertainty here, but this uncertainty is at present inevitable.

In Germany there is a tendency to the more liberal use of protein. The ration proposed by the Wisconsin Station advocates less protein and more of the fuel ingredients of the food. Because carbohydrates and fats are so abundant and so cheap in this country that we feed them liberally does not imply, much less prove, that we are using them wisely.

Wide vs. Narrow Rations.

RESULTS OF TESTS IN 1892-93.

There are so few American data upon the effects of rations, that the teachings of the studies of the herds made by the Station upon this question are of some value.

Summary of rations fed and yields of butter obtained from sixteen herds examined in 1892-93. The yields of butter are classified in accordance with the nutritive ratios of the ration and the amounts of digestible protein which they contain.

SUMMARY OF RATIONS FED PER HEAD.						DAILY AVERAGE YIELDS OF BUTTER* PER COW.			
Herd No.	Average Weight of Cows.	Total Organic Matter.	Digestible Protein.	Nutritive Ratio.	Fuel Value of Digestible Nutrients.	Nutritive Ratio.		Digestible Protein.	
						Greater than 1:6. Wider Rations.	Less than 1:6. Narrower Rations.	More than 2.2 Pounds.†	Less than 2.2 Pounds.†
	Lbs.	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs.	Lbs.
1, - -	900	22.9	2.25	6.0	30,100	—	1.1	1.1	—
2, - -	800	21.8	2.24	6.0	29,600	—	1.0	1.0	—
3, - -	800	21.5	2.40	5.5	30,350	—	1.2	1.2	—
4, - -	800	25.0	2.08	7.0	31,850	0.8	—	0.8	—
5, - -	800	23.7	2.52	5.5	31,500	—	1.0	1.0	—
6, - -	900	23.9	1.85	8.0	31,050	0.9	—	—	0.9
7, - -	800	25.6	1.96	8.5	34,100	1.1	—	1.1	—
8, - -	740	24.9	2.33	6.0	30,600	—	1.0	1.0	—
9, - -	900	20.5	1.93	6.5	26,950	0.9	—	—	0.9
10, - -	850	20.7	1.95	6.5	27,300	1.2	—	1.2	—
11, - -	825	21.8	2.27	5.5	28,400	—	0.9	0.9	—
12, - -	875	20.5	2.62	4.5	26,900	—	1.3	1.3	—
13, - -	800	16.4	1.76	6.0	23,000	—	0.8	—	0.8
14, - -	875	22.9	2.32	6.0	29,550	—	1.1	1.1	—
15, - -	850	20.2	1.15	11.5	26,250	0.8	—	—	0.8
16, - -	900	20.5	1.30	9.5	26,650	0.9	—	—	0.9
Average,	850	22.0	2.06	6.5	29,000	0.9	1.0	1.1	0.9

* Butter assumed to contain 85 per cent. of butter-fat.

† More or less than 2.2 lbs. per 1,000 lbs., live weight.

In the table are summarized the rations fed in the herds studied in the winter of 1893, together with the daily yield of butter during the five days of each test. The animals were of different breeds, and in many ways the conditions were such that the results are not strictly comparable one with the other. In the lack of better data the results are put together in the table to show what light they may throw upon the question of the effect of protein and the nutritive ratio upon the production of butter.

The average daily butter yields are grouped by size of the nutritive ratio of the rations and the weights of protein fed. The animals having the narrower rations produced on the average one-tenth of a pound more of butter per day than those having the wider, and those having the larger amounts of protein gave on the average two-tenths of a pound more of butter per day than those having the smaller quantities of protein. Too much importance should not be attached to these results, as they may have been partly accidental and due to causes other than feed. It is, nevertheless, a noteworthy fact that in the cases in which the cows were in about the same period of lactation, the yields of butter decreased as the protein decreased, and as the nutritive ratio increased. This would seem to indicate that it would be safe in general to feed as much or even more protein than called for by Wolff's standard ration if we would obtain the largest yields of butter from our milch cows. It would also, perhaps, be wiser until we have more light than at present, to make our rations larger, so far as their total energy is concerned, than the German standard. The size of the ration suggested by the Wisconsin Station as a standard ration, when it is measured by its fuel value, may not be too large for the demands of our conditions. Feeding stuffs rich in carbonaceous foods (fats and carbohydrates) are abundant and cheap with us, and it is sometimes difficult to utilize the foods produced on the farm without making a ration larger in total energy than the German standard calls for.

TESTS OF 1893-94.

In the tests of 1892-93 it is not practicable to compare the cost of production upon narrow and wide rations since the rations differed with different herds. In the winter of 1893-94 tests were made with the same herds on wide and narrow rations, and the financial as well as the physiological results could be observed. The outcome of this work is briefly given here.

Samples of the different feeding stuffs used in the test were taken early in each test and sent to the laboratory for analysis.

As soon as it was possible to obtain the results of the analyses, the ration fed was calculated and suggestions were made for changes in the ration. After changes had been made and the animals had been upon the new ration for a week or longer, the herd was again visited and a new twelve-days' test was made.

The prices of feeding stuffs which are used in calculating cost of the rations fed were current in December, 1893. The manurial value is based upon figures given in the Report of the Massachusetts Agricultural Experiment Station for 1893, pp. 358-365. The nitrogen in the feeding stuff is counted as worth $17\frac{1}{2}$ cents, the phosphoric acid at 5 cents, and the potash at $5\frac{1}{2}$ cents per pound for manure, and it is assumed that 85 per cent. of the quantities in the food may be saved in the manure. Unfortunately most farmers care for manure so poorly that a much smaller percentage is usually saved.

Valuation of Feeding Stuffs as used in Rations Fed Milch Cows in Winter of 1893-94.

FEEDING STUFFS.	Market Price per Ton of Feeding Stuffs.	Estimated Value of the Manure Obtainable from One Ton of Feeding Stuffs.
Wheat bran, - - - -	\$19.00	\$13.00
Corn meal, - - - -	21.00	8.00
Cotton seed meal, - - -	26.00	27.00
Cob meal, - - - -	20.00	6.00
Linseed meal, O. P., - -	30.00	22.00
Chicago gluten, - - - -	25.00	18.00
Rye meal, - - - -	21.00	8.00
Oat feed, - - - -	21.00	9.00
Corn ensilage, - - - -	2.50	1.75
Hay, - - - -	18.00	6.00
Oat hay, - - - -	14.00	6.00
Corn stover, - - - -	8.00	5.50
Oat straw, - - - -	10.00	6.00
Bog hay, - - - -	8.00	4.50

HERD A.—TESTS 18 AND 21.

A dairy farm was visited by a Station representative December 4-16, 1893, and after an interval of four weeks it was again visited (January 15-27). There were 19 cows in each test, but four of them were changed between the two tests.

The following discussion includes only the 15 animals entering into both tests. These included 10 Guernseys, 4 Jerseys, and 1 Ayrshire. The average estimated weight was 825 pounds each. The average age was five years. At date of first test the average time since last calf was dropped was five months. None of the cows were within four months of calving. The statistics of the rations fed are summarized in the following table.

The German standard and the ration tentatively suggested on page 46 of this Report and calculated for animals of 825 pounds, live weight, are appended for comparison.

DAIRY HERD A. TESTS 18 AND 21.
Calculated Per Head of 825 Pounds, Live Weight.

FEEDING STUFFS.		DIGESTIBLE NUTRIENTS AND FUEL VALUE.					Cost.	Value of Obtain- able Manure.	Net Cost.
Kind.	Amount.	Protein.	Fat.	Carbo- hydrates.	Fuel Value.	Nutritive Ratio.			
<i>First Test.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Calories	1:	Cts.	Cts.	Cts.
<i>December 4-16. 12 Days.</i>									
Grain, { Wheat bran, -	5.1	1.49	.45	4.63	13,300	3.9	10.4	6.4	4.0
etc., { Corn meal, -	3.8								
etc., { Cot. seed meal, -	1.2								
Hays, { Corn ensilage, -	10.0	.66	.37	8.94	19,450	15.0	16.2	5.9	10.3
etc., { Hay, - - -	16.6								
Total food, - -	36.7	2.15	.82	13.57	32,750	7.3	26.6	12.3	14.3
<i>Second Test.</i>									
<i>January 15-27. 12 Days.</i>									
Grain, { Wheat bran, -	5.4	1.81	.49	4.25	13,300	3.0	10.8	7.5	3.3
etc., { Corn meal, -	2.7								
etc., { Cot. seed meal, -	2.2								
Hays, { Corn ensilage, -	12.6	.58	.33	7.32	16,100	13.9	10.9	4.4	6.5
etc., { Hay, - - -	8.0								
etc., { Oat hay, -	3.0								
Total food, - -	33.9	2.39	.82	11.57	29,400	5.7	21.7	11.9	9.8
German standard, -	—	2.06	.33	10.31	24,400	5.4	—	—	—
Standard tentatively suggested, - -	—	2.06	—	—	25,600	5.6	—	—	—

The second ration as fed was larger and hence more expensive than was intended; nevertheless the total cost of the second ration was 5 cents less per head and the net cost was 5½ cents less than the first. The use of cotton seed meal reduces the net cost of the second ration very materially, for the estimated value of the manure obtainable from cotton seed meal equals its cost.

HERD B.—TESTS 20 AND 23.

Another herd was studied from January 2 to January 14, 1894, and a second test of the same herd was made February 12-24, 1894, after an interval of four weeks.

There were 16 cows in the herd tested, 15 of which were in both tests. These included 10 grade Jerseys and 5 "natives." The average weight of each cow was 750 pounds. The average age was six years, and at time of first test the average time since dropping last calf was three months. None of the cows were within six months of again calving. The rations were as follows:

DAIRY HERD B. TESTS 20 AND 23.

Calculated Per Head of 750 Pounds, Live Weight.

FEEDING STUFFS.		DIGESTIBLE NUTRIENTS AND FUEL VALUE.					Cost.	Value of Obtain- able Manure.	Net Cost.
Kind.	Amount.	Protein.	Fat.	Carbo- hydrates.	Fuel Value.	Nutritive Ratio.			
<i>First Test.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Calories	1:	Cts.	Cts.	Cts.
<i>January 2-14. 12 Days.</i>									
Grain, { Cob meal, -	6.2 }	.92	.29	4.82	11,850	6.1	9.1	3.8	5.3
etc., { Wheat bran, -	2.9 }								
	2.2 }								
Hays, { Corn stover, -	8.7 }	.57	.19	6.50	13,950	12.4	9.5	5.3	4.2
etc., { Bog hay, -	1.2 }								
	6.3 }								
Total food, - -	27.5	1.49	.48	11.32	25,800	8.5	18.6	9.1	9.5
<i>Second Test.</i>									
<i>February 12-24. 12 Days.</i>									
Grain, { Cob meal, -	2.5 }	1.47	.32	4.04	11,550	3.3	9.2	5.4	3.8
etc., { Bran, -	4.0 }								
	2.3 }								
Hays, { Oat straw, -	1.8 }	.54	.18	6.12	13,150	12.2	9.1	4.9	4.2
etc., { Corn stover, -	7.3 }								
	1.2 }								
	6.9 }								
Total food, - -	26.0	2.01	.50	10.16	24,700	5.7	18.3	9.3	9.0
German standard, -	—	1.88	.30	9.38	22,200	5.4	—	—	—
Tentative standard, -	—	1.88	—	—	23,250	5.6	—	—	—

In both rations coarse fodders are largely used. These make the rations cheaper than if good hay had been used. The use of these hay substitutes is to be commended, although they necessitate the use of concentrated foods rich in protein. The ration as

fed in the first test was a low cost one, and it would be difficult to furnish the needed grain feed at much lower cost. The assumed value of the coarse fodders is probably higher than they would bring in market; and their use in this way disposes of them at a good price.

HERD C.—TESTS 22 AND 25.

A herd of 16 cows was studied from January 29 to February 10, 1894, and after an interval of four weeks another 12-days' test of the same herd was made, March 5-17. Fourteen of the cows were in both tests. These included 6 grade Jerseys, 2 grade Durhams, and 6 "natives." The average weight of the cows was 725 pounds. The average age was five years and, at the date of the first test, the average time since dropping the last calf was six months. With one exception none were within three months of being due to calve again. The rations were as follows:

DAIRY HERD C. TESTS 22 AND 25.

Calculated Per Head of 725 Pounds, Live Weight.

FEEDING STUFFS.			DIGESTIBLE NUTRIENTS AND FUEL VALUE.						Cost.	Value of Obtain- able Manure.	Net Cost.
Kind.	Amount.	Protein.	Fat.	Carbo- hydrates.	Fuel Value.	Nutritive Ratio.					
<i>First Test.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Calories	1:	Cts.	Cts.	Cts.		
<i>Jan. 29-Feb. 10. 12 Days.</i>											
Grain, { Cob meal, -	4.3	.77	.21	3.66	9,150	5.4	7.2	3.3	3.9		
etc., { Wheat bran, -	3.0										
Hays, { Stover, -	3.5	.61	.20	5.41	12,000	9.6	12.2	3.6	8.6		
etc., { Oat hay, -	3.9										
{ Hay, -	4.5										
Total food, -	19.2	1.38	.41	9.07	21,150	7.3	19.4	6.9	12.5		
<i>Second Test.</i>											
<i>March 5-17. 12 Days.</i>											
Grain, { Cot. seed meal, .4	}	1.16	.29	3.67	10,200	3.8	8.1	4.2	3.9		
{ Linseed meal, .4											
{ Chicagogluten, .4											
{ Cob meal, 4.0											
Hays, { Wheat bran, - 2.6	}	.64	.22	5.42	12,200	9.4	9.7	3.7	6.0		
etc., { Hay, -										5.9	
{ Oat hay, -										6.3	
Total food, -	20.0	1.80	.51	9.09	22,400	5.7	17.8	7.9	9.9		
German standard, -	—	1.81	—	9.06	21,450	5.4	—	—	—		
Tentative standard, -	—	1.81	.29	—	22,500	5.6	—	—	—		

The second ration cost a cent and a half a head less than the first, and taking the manurial value into account there is a saving of $2\frac{1}{2}$ cents per day in net cost of food. The second ration agrees very closely with the tentatively suggested standard ration.

These six tests with three herds are summarized in the following table:

Summary of Daily Rations Fed, and Daily Milk and Butter Yield from Three Herds with a Wide and a Narrower Ration.

HERD.	Average Weight of Cows.	No. of Test.	DAILY RATION PER HEAD.*					AVERAGE DAILY.		COST OF FOOD TO PRODUCE.			
			Digestible Protein.	Fuel Value of Digestible Nutrients.	Nutritive Ratio.	Total Cost.	Net Cost.†	Milk Flow.	Yield of Butter.‡	100 lbs. Milk.		1 lb. Butter.	
										Total Cost.	Net Cost.†	Total Cost.	Net Cost.†
	Lbs.		Lbs.	Calories	1:	Cts.	Cts.	Lbs.	Lbs.	\$	Cts.	Cts.	Cts.
A, -	825	18	2.15	32,750	7.3	26.6	14.3	18.1	1.07	1.47	79	25	14
		21	2.39	29,400	5.7	21.7	9.8	18.9	1.09	1.15	52	19	9
B, -	750	20	1.49	25,800	8.5	18.6	9.5	18.1	.87	1.00	53	21	11
		23	2.01	24,700	5.7	18.3	9.0	17.9	.89	1.03	50	20	10
C, -	725	22	1.38	21,150	7.3	19.4	12.5	13.7	.65	1.41	91	30	19
		25	1.80	22,400	5.7	17.8	9.9	13.6	.69	1.30	73	26	14
D.§	825	-	2.06	25,600	5.6	—	—	—	—	—	—	—	—
	750	-	1.88	23,250									
	725	-	1.81	22,500									

* These rations are given in detail on pages 31, 35-36, 38 and 50-52.

† Total cost less value of the obtainable manure.

‡ Butter assumed to contain 85 per cent. butter-fat.

§ Tentatively suggested standard ration.

THE EFFECT OF NARROW RATIONS ON MILK FLOW AND BUTTER YIELD.

At the time of the second test in each case the cows were six weeks farther along in the period of lactation and would in consequence have naturally reduced their milk flow and butter yield. It is impossible to say exactly how much this natural shrinkage would have been. In animals as near calving as some of these were the shrinkage would have probably been large, while in the case of the cows in "flush" the decrease would have been less marked. From a record of a herd of native cows and Ayrshires extending over 15 years, including 83 different animals and 210 calvings, the New York Experiment Station* concluded that "the natural falling off in milk for each month from calving

* Annual Report New York Agricultural Experiment Station, 1886, pp. 21-23.

is about 9 per cent. of the yield of the preceding month." The shrinkage in butter yield would, of course, be less, because the milk grows richer in fat.

In the case of herd A, instead of a falling off in milk flow there was an average daily increase of seven-tenths of a pound in the test while they were fed the narrow ration over what it had been with the wide ration six weeks earlier. There was practically no change in milk flow in the case of the two other herds. With all three herds there was a slight increase in butter yield with the narrow ration in the second test. The total size of the ration as measured by the fuel value averaged less in the second test than in the first. The protein was increased and the carbohydrates and fats were decreased in the second test.

In these cases both milk flow and butter yield were so much affected by the change from a wide to a narrow ration that instead of a shrinkage in production, as would naturally follow from advancement in period of lactation, the animals more than held their own. Too much importance should not be given to a few results, but these are in line with the best observations here and elsewhere, that so far as physiological effects are concerned, narrow (nitrogenous) rations give larger yields of both milk and butter than do wide (carbonaceous) rations.

COST OF MILK PRODUCTION WITH WIDE AND NARROW RATIONS.

The following tabulations indicate that the cost of milk and butter production from the food alone was much less on the narrow ration, even when the cows were six weeks farther advanced in lactation than earlier on the wide ration. So far as these tests may be taken as an indication, narrow rations may be fed more profitably than wide.

The cost of food to produce 100 pounds of milk was as follows:

HERD.	TOTAL COST OF FEED.		NET* COST OF FEED.	
	Wide Ration.	Narrower Ration.	Wide Ration.	Narrower Ration.
A, - - - -	\$1.47	\$1.15	\$0.79	\$0.52
B, - - - -	1.00	1.03	.53	.50
C, - - - -	1.41	1.30	.91	.73
Average, - -	\$1.29	\$1.16	\$0.74	\$0.58

* Total cost less value of obtainable manure.

The cost of food to produce one pound of butter was as follows:

HERD.	TOTAL COST OF FEED.		NET* COST OF FEED.	
	Wide Ration.	Narrower Ration.	Wide Ration.	Narrower Ration.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
A, - - - -	25	19	14	9
B, - - - -	21	20	11	10
C, - - - -	30	26	19	14
Average, - -	25	22	15	11

*Total cost less value of obtainable manure.

In 1893 we visited a dairy farm on which the cows (a herd of grade Jerseys) were receiving a very wide ration. The ration as fed contained per 1,000 pounds, live weight, only 1.35 pounds digestible protein. The nutritive ratio was 1 to 11.3. In 1894 we again visited this farm, intending to make a 12-days' test with the old method of feeding and later another test with a narrow ration. But it transpired that the owner had meanwhile caught the idea himself and had changed his feeding practice very materially. We made a 12-days' test and found that instead of a wide ration he was feeding a narrow one, and one that we had not the hardihood to attempt to improve. He was feeding 2.70 pounds digestible protein per 1,000 pounds, live weight, or double the amount of the year before, and the nutritive ratio was 1 to 5.7 instead of 1 to 11.3. The gross cost of the ration for 1893 was 23 cents per 1,000 pounds, live weight, and in 1894, 22 cents. The net cost in 1894 was 9 cents against 13 cents in 1893. The average weight of the herd was practically the same both years. The 5-days' test of 1893 and the 12-days' test of 1894 compare as follows:

TOTAL COST OF FOOD TO PRODUCE				NET* COST OF FOOD TO PRODUCE			
100 Lbs. Milk.		1 Lb. Butter.		100 Lbs. Milk.		1 Lb. Butter.	
Wide Ration.	Narrow Ration.	Wide Ration.	Narrow Ration.	Wide Ration.	Narrow Ration.	Wide Ration.	Narrow Ration.
1893.	1894.	1893.	1894.	1893.	1894.	1893.	1894.
\$1.44	\$1.08	24 cts.	19 cts.	81 cts.	51 cts.	14 cts.	9 cts.

*Total cost less value of obtainable manure.

It would be difficult to convince this man that it did not pay him to change from a wide to a narrow ration.

SUMMARY.

In the winter of 1892-93, the Station began making systematic observations of the winter feeding practices of Connecticut dairymen. The chief points upon which information was obtained were: Number of animals in the herd; breed, age and approximate weight of each cow; length of time since dropping last calf and till due to calve again; weights of milk flow; percentages and amounts of butter-fat in the milk; kinds, weights and chemical composition of feeding stuffs used.

In 1892-93 sixteen herds were visited and a five-days' test made with each. In 1893-94 six herds were visited, and in four instances the time of study of the management and products of each were extended to twelve days. As soon as the analyses could be made the rations were calculated, and in three cases other rations were suggested. The feed was gradually changed to the suggested ration, and after four weeks from the close of the first test another twelve-days' test was made with the new ration.

In general there was the largest yield of milk and the largest butter production with narrow rations rich in protein. Wide rations, low in protein, did not in these instances favor large milk or butter production.

In the three tests of 1893-94, when it was possible to study the financial side of the feeding, narrow rations, rich in protein were decidedly the more economical.

Bearing in mind that there is no such thing as a "best ration," and that all attempts to express in terms of protein and energy the needs of a dairy cow are only approximations, the following ration is tentatively suggested as a basis for feeding dairy cows:

Organic matter, 25 pounds; digestible protein, 2.5 pounds, and enough digestible fat and carbohydrates to bring the fuel value up to about 31,000 Calories.

The subject of cattle feeding and handling is a large one, and only general principles can be laid down. No hard and fast rules for feeding are now known, and doubtless none ever will be known. It is nevertheless true that the man who exercises the greatest amount of good judgment, based upon all that the most advanced science can bring to him, and who tries to put into practice the knowledge thus acquired, will be much surer of success than one who works blindly. There may be no "best" breed, no "best" ration, and no "best" way of handling dairy stock, but there are poor cows, uneconomical rations, and bad ways of handling, and the man who learns to avoid the bad and choose the better is well on the road toward the best.

BACTERIA IN THE DAIRY.*

BY H. W. CONN.



VI. EXPERIMENTS IN RIPENING CREAM WITH BACILLUS NO. 41.

In Bulletin No. 12 of this Station was published the result of a series of experiments that had been carried on in the laboratory upon the subject of the ripening of cream. In that Bulletin there were mentioned a series of preliminary experiments with *Bacillus No. 41*, which gave most promising results as an organism for artificial ripening of cream in butter-making. During the whole of the past year, further experiments have been carried on with this organism in a variety of places, with results which are extremely satisfactory and promise to be of much practical importance. The experiments with the organism have been so satisfactory that a more careful description of the organism itself and a more complete account of the experiments with it appear to be needed, and the present article, therefore, is designed to give these details.

The original culture of *Bacillus No. 41* was obtained from a lot of milk which had been sent to the Columbian Fair at Chicago among the food exhibits. It was said to be "preserved," but had not been thoroughly sterilized and had become bitter. There had developed in the milk a number of organisms which were isolated by Mr. W. M. Esten, who had charge of the biological exhibit, and among them *Bacillus No. 41* was found. The characteristics of this organism are as follows:

Locality.—Milk from Uruguay.

Morphology.—A bacillus occasionally clinging two together but never forming chains. Size 1.1 μ . by 6 μ . When growing in potato it is slightly longer than in agar. No spores.

Motility.—Non motile.

* During the past seven years investigations on the Bacteria of Milk have been conducted in behalf of the Station by H. W. Conn, Professor of Biology in Wesleyan University. Some of the results have been given in the publications of the Station, as follows: *Bacteria in Milk, Cream, and Butter*, Bulletin 4, and Annual Report for 1889, pp. 52-67. *Ripening of Cream*, Annual Report for 1890, pp. 136-157. *A Micrococcus of Bitter Milk*, Report for 1891, pp. 158-162. *The Isolation of Rennet from Bacteria Cultures*, Report for 1892, pp. 106-126. *The Ripening of Cream by Artificial Cultures of Bacteria*, Bulletin 12 and Report for 1893, pp. 43-68. See also *The Fermentations of Milk*, Experiment Station Bulletin No. 9 of the Office of the Experiment Station of the U. S. Department of Agriculture.

Relation to air.—Will not grow under mica plate.

Temperature.—Grows best at about 20–23° C.; at 35°, scarcely any growth;* killed by temperature of 60° C. to 10 minutes.

Colony on Gelatine.—A smooth, round colony under surface. On surface a small, grey, raised bead-like colony, spreading somewhat, reaching size of 1 mm. occasionally. Not characteristic.

Gelatine Stab Culture.—Slight needle growth. Spreads over surface as a moist, white, thick mound, forming a nail growth. Does not liquefy.

Agar-Agar.—An abundant, white, smooth, glistening layer.

Potato.—Raised, thick, whitish or slightly yellow-tinged layer. Differing in color with amount of moisture. When very moist, is white, but when dry tends to a yellowish tinge. Grows profusely.

Milk.—Does not curdle either at 20° or 35°. After two to three weeks becomes slightly translucent and brownish. The reaction is slightly acid. After three to four weeks it seems to digest into a translucent mass. It acquires a pleasant aroma.

Bouillon.—Very cloudy with heavy scum. After five days scum sinks and forms a sediment. Liquid remains cloudy after a month's growth.

From the above description it will be noticed that the organism, while forming an acid in its growth in milk, is not to be regarded as one of the milk-souring organisms. Milk under its influence becomes acid, but the acid production is quite slight and the milk, under no condition, becomes curdled. Even when growing at a warm temperature the milk remains limpid for weeks, finally becoming somewhat brownish. After cultivation of the organism for a year or more in the laboratory, its acid-producing powers seem to be somewhat greater than at first.

This organism has proved the best of all of the many species of bacteria thus far studied in its effect upon cream in ripening. Preliminary experiments with the organism have already been described, and by reference to Bulletin 12 of this Station it will be seen that those experiments, both in the laboratory with small lots of butter and in a neighboring creamery, gave promise of the possibility of the production of an excellent butter. The further continuation of those experiments from the time of the publication of Bulletin 12 will be now described.

METHOD OF EXPERIMENT.

It may be well first to explain the method of experiment which has been found after considerable trial to be, all things considered, the most satisfactory. Thus far the organism has been

* After a year's cultivation it failed to grow at 35°, although would do so feebly when first studied.

cultivated solely in the writer's bacteriological laboratory and upon ordinary culture media.

When experiments in the creamery or elsewhere are desired, the procedure is as follows: There is first placed in an ordinary flask a half pint of milk, and this is sterilized by discontinuous steaming for three or four successive days. This sterilized milk is inoculated with a small amount of the *Bacillus No. 41*, and the culture thus made is allowed to grow at about 23° C. (74° F.) for a couple of days. The object of this growth is merely to increase the number of bacteria and thus make a larger inoculation in the creamery possible. After two days' growth the culture is sent to the creamery and the rest of the experiment is performed there by the butter-maker.

A lot of cream, amounting to six or eight quarts, is placed in a metal vessel and pasteurized, by being put into a tub of water into which steam is allowed to run. The temperature of the cream is allowed to rise to about 69° C. (156° F.) and to remain there for some ten minutes. The cream vessel is then removed and placed in cold water and cooled as rapidly as possible. When the temperature has fallen to about 23° C. (74° F.) the milk culture of the bacillus above described is poured into it and is thoroughly mixed with it by stirring. The vessel is then covered and placed in the ripening room of the creamery for two days, at the end of which time the cream is churned and the buttermilk reserved for further use. The object of this ripening of a lot of six quarts of cream is to increase the number of bacteria in order that a large and strong culture may be obtained for use in the large vat of cream in the creamery. The buttermilk from the churning of the six quarts of cream is then inoculated into the day's cream as soon as the cream is placed in the vat for ripening. The cream in the large vat receives no preliminary treatment, the prepared milk being poured into it directly. The cream is then allowed to ripen at a normal temperature for about twenty-four hours and churned as usual. Before the churning two or three gallons of the ripened cream is set aside to be added to the next day's cream collection to insure a continuation of the process. In this way the ripening is continued day after day, a small amount of each day's churning being set aside for the next day's inoculation, and the process is continued as long as the good effects of the original culture are seen. In the series of experiments which were instituted it was

found that the effect of the first culture could be kept up in this way from three to six weeks, after which a new pure culture from the bacteriological laboratory was needed.

It will be noticed in these experiments that in practical use the cream of each day's gathering is not pasteurized nor treated in any way to insure removal of the bacteria which chance to be in it. It may seem strange that under these conditions the addition of a pure culture would have decided effect upon the ripening of the cream. The explanation of the matter seems, however, to be simple. As is well known, a properly ripened cream needs to be slightly acid in order to give the flavor which is usually desired. Now *Bacillus No. 41* does not produce sufficient acid to give this flavor, and in laboratory experiments with strictly pure cultures upon pasteurized cream it is found that the flavor of the butter is somewhat too flat. The cream as is ordinarily collected for the creamery contains organisms which render it acid, and when, therefore, *No. 41* is added to the ordinary cream the effect of this culture is enhanced by the acid produced by the organisms already present. There is thus obtained a cream which is acid and also influenced by the peculiar effects of *No. 41*. Moreover, the culture bacteria were always added in excess. By cultivating as above described for several days in larger lots of cream, and by adding to the day's collection of cream two or three gallons of buttermilk or ripened cream, the number of bacteria of *Bacillus No. 41* added to the lot of cream was so great that their effects were plainly noticeable, in spite of the presence of the other species of bacteria which were in the cream as originally collected.

RESULTS OF THE INOCULATION.

In a long series of experiments the effect of the method of inoculation above described was always uniform and as follows: The first lot of cream, six or eight quarts, gave a butter which was moderately good, containing a somewhat pleasant flavor, but not quite the typical flavor desired. The first churning in the large lot of butter from the ordinary cream vat gave butter slightly superior to that in the small churning. Then, on each day for several successive churnings, the quality of the butter improved. For perhaps one or two days it was a little difficult to say that the artificial culture had produced much of an improvement, the butter having about its ordinary flavor. But after

two or three days there began to be noticed a pleasant *added* flavor which was not there at first, and after several days' churning this added flavor became very pronounced and noticeable to all who examined the butter. This delicate, exquisite flavor now continued and remained in the butter of each day's churning for some time, the length of time varying with, at present unknown, conditions. If the flavor began to deteriorate it could be immediately restored by the addition of a new culture from the laboratory by the same method above described, and there is thus no difficulty in constantly maintaining this flavor in the butter.

The general results in the creamery at Cromwell where most of these experiments have been performed, have been as follows: The experiments began in November, 1893, and there was noticed an immediate improvement in the butter. These experiments have been continued constantly with the exception of the months of July, August and September, until the present time and with uniform results. During this time pure cultures have been sent to the creamery upon many different occasions and have been used according to the above method. In each case there was an improvement in the butter, and the experiment was continued for three, four, five or six weeks, until the butter-maker noticed a distinct deterioration in the quality of his butter. Then a new culture was sent to the creamery which immediately restored the quality to the butter.

At four distinct periods the butter from the creamery was sent to an expert for rating, together with a lot of butter made from half of the same cream of the same day, but without the artificial inoculation. In *every case* where the butter was thus sent the butter made by the artificial culture was rated higher than the butter made without it. It was marked from four to fifteen points on a scale of 100, ahead of the normal butter, the improvement being chiefly in the flavor. In one case the inoculated butter was 18 points ahead of the uninoculated butter. In another case three lots were sent to the expert, one made with a culture of *Bacillus No. 41*, a second made with the artificial culture sold by Carl Hansen's dairy company, and a third lot by a combination of *Bacillus No. 41* and Carl Hansen's ferment. The butter made from *Bacillus No. 41* rated highest, 95 points, the combination next 83 points, and Carl Hansen's lowest. In addition to the rating by the butter expert the butter was in all

cases carefully examined by individuals who were more or less connoisseurs of proper butter flavor, and in each instance the butter made by the artificial culture was rated as better than that made without such culture. In most of these tests the individual examining the butter had no knowledge of the experiment.

Perhaps the most satisfactory experiment of all was one made early in June. June butter, as is well known, is in flavor about the best that is produced during the year, and the effect of *Bacillus No. 41* upon June butter was therefore especially interesting. Early in June, when the amount of cream collected by the creamery was very large, two large vats full of cream were collected. One of these was inoculated with *No. 41* and the other was uninoculated. They were then both allowed to stand in the same room at the same temperature for the same length of time to ripen, and were subsequently churned. The effect of *No. 41* even here was exceptionally striking. Both lots of cream produced, as was to be expected, an excellent quality of butter, but *No. 41* had an aroma more pronounced and more agreeable than that of the butter made without the inoculation. In both taste and odor the butter made by inoculation was decidedly superior to that made without it. This butter was submitted for testing to a large number of persons, and no one had the slightest hesitancy in deciding that *No. 41* made the superior quality of butter. It was most strikingly noticed just as soon as the wrapper was taken from the butter, the pleasant aroma of the inoculated butter filling the nostrils at once, while the uninoculated butter did not possess this decidedly pleasant aroma and taste.

The general result of experiments thus carried on now for at least twelve months in the Cromwell creamery, has been that this artificial culture uniformly improves the value of the butter. The effect of the pure culture is seen best after two or three days' ripening, and lasts from three to six weeks, but by the constant use of the culture it may be kept up indefinitely.

Mr. E. D. Hammond, the superintendent of the Cromwell creamery, has put in my hands the following letter, indicative of the experiments carried on in his creamery:

H. W. Conn:

December 20, 1894.

MY DEAR SIR:—In reply to yours of the 19th I will say that we have used your culture the past year, with the exception of the summer months when you were away and we could not get it. There can be no doubt as to its producing

butter of a superior and uniform quality. In every instance where we have taken a quantity of cream, thoroughly mixed, and divided it into two parts, and have treated one in the usual way and have inoculated the other with the culture, and have sent the product to an expert to be judged, the culture has scored the highest. It produces a fine, sweet flavor which leaves a most pleasing taste in the mouth. For the sweet butter trade it is decidedly superior.

Yours truly,

E. D. HAMMOND.

It was, of course, desirable that these results should be confirmed in other places, and for this reason the culture has been used in several localities. These experiments have been as follows:

One lot of the culture was sent to Mr. George M. Whitaker of West Dudley, Mass. The creamery of which he is president was making at the time the highest quality of butter, which commanded a very high price in the Boston markets. The culture sent was broken in the journey and only a small amount of it reached the creamery. It was, however, used by Mr. Beck, the butter-maker of the creamery, and his statement was that he noticed a decided improvement in the quality of his butter as the result of it. Owing to the distance and the consequent difficulty of furnishing the culture at this creamery the experiments were not continued, only one churning being made with the culture.

A culture of the bacteria was sent to Mr. Hollister Sage, superintendent of the creamery at Stepney Depot, Conn. The culture sent to this place for necessary reasons, was not a culture in milk, but an ordinary bacteria culture on agar-agar, and required the use of certain bacteriological methods in its practical application to cream. Mr. Sage, however, seemed to have no difficulty in making use of it as directed and reported, after the proper length of time, that he had noticed a decided and pleasant flavor to his butter, which was not there before and which gave it an enhanced value. Several months later a second culture was sent him in a different form, but no report from it has yet been received.

Up to this point the experiments had been practically confined to Middletown and the immediate vicinity. It was of course very desirable that they should be repeated in other localities and by other persons, in order to determine whether the effect was local only, and to what extent other creameries besides the Cromwell creamery, would be benefited by the use of *Bacillus No. 41*.

During the last three months therefore, arrangements have been made by which the organism has been used in other States. These experiments have now been made in the State of Indiana, in the creamery of R. W. Furness, Indianapolis. In Pennsylvania the organism has been introduced into some thirty-five different creameries through the assistance of Mr. John Jamison, a large commission merchant of Philadelphia. In Iowa it has also been introduced into twenty-eight creameries controlled by Wm. Beard & Sons, commission merchants in Decorah, Iowa. The experiments in this large number of creameries have been most rigid. In many cases a lot of cream has been divided into two portions, one of which has been inoculated and the other not, the resulting butter being compared carefully. In some instances the organism has been inoculated into old cream which had acquired considerable of an odor by standing. In several instances it has been used in creameries in which the quality of the butter has not been first-class, and in others it has been used in creameries of the highest grade, whose butter commanded high market prices. In two instances it has been used in creameries which were at the time troubled with an undesirable flavor due to what is known as "frost weed." The butter made in the various creameries has been submitted for testing to experts, who in some cases knew of the experiments, and in others knew nothing of them. The butter made by the use of the culture was kept in the creamery side by side with the ordinary butter to test its keeping property. In short, the greatest variety of tests have been tried in this large series of creameries to determine whether the organism really possesses in other localities the valuable property that it has appeared to possess in the experiments conducted in Connecticut.

The results of these experiments have been highly satisfactory and to me somewhat surprising, in spite of my belief in the value of the organism in butter-making. With a single exception none of this large series of creameries has failed to report an improvement in their butter. The creamery which did not find such improvement was reported as failing to have proper care for cleanliness in its butter-making process, and the failure to find an improvement has not therefore been thought to be significant. All other creameries in this large number of over sixty have found an improvement in their butter, sometimes appearing at once, and in other cases appearing after a few days use of the

artificial inoculation. In private letters mentioning the experiments Mr. Furness says: "The indications are that there is a decided improvement in both the keeping qualities and the flavor of the butter." Mr. S. F. Doolittle, a commission merchant in Indianapolis, says: "There is a decided improvement in the butter made with the culture over the butter made *with the same cream* without the culture. The butter made with the culture has a 'grass flavor.'" Mr. Jamison says: "We feel satisfied that the butter from any creamery can be improved to such an extent that the butter will bring from two to three cents per pound more on its merits than before using the culture." Wm. Beard says: "I consider this *Bacillus* the greatest discovery known for producing a high and uniform flavor in butter. We also believe it will greatly increase the keeping qualities of the butter."

The value of this testimony from such widely separate sources is evident at once. It shows two things especially. First, that the effect of *Bacillus No. 41* in improving butter is not confined to Connecticut or New England; and second, that the effect is not imaginary upon the part of those interested in the experiments in this Station. Each of these creameries in which the experiments have been begun has continued the use of the artificial inoculation, and all are using it at the present time of writing. When creameries in Connecticut, Iowa and Pennsylvania all alike report a decided improvement in the butter, we are justified in concluding that *Bacillus No. 41* has the power of adding to butter a desirable flavor in widely separated localities under different conditions and as determined by different experts.

When these experiments were begun it was doubted whether the use of the culture in private dairies would be practicable. The long period during which the cream is being collected frequently makes the cream four or more days old before it is churned. It is quite possible that the growth of the ordinary cream bacteria would be so great in this interval as to interfere with the action of the artificial culture. The first experiment of the kind was performed in a dairy in the vicinity of Middletown. Mr. F. T. Kurt told me in June that in his creamery they had been having trouble with the appearance of "curds" in the butter, a difficulty with which every butter-maker is more or less familiar. This trouble had been proving a great nuisance

in the dairy and had continued in spite of their attempts to get rid of it. He wanted to know if it was possible that a culture of *Bacillus No. 41* might improve his butter. He was told that it was doubtful if the culture would have much effect upon the curds, but that it might perhaps improve the butter. He therefore obtained a culture and used it in accordance with the above method and reported an immediate and a striking improvement in the butter. The curds disappeared in the butter that was ripened by the artificial culture, and every one to whom the butter was submitted stated that it was decidedly superior to the butter that had been made previously. The experiments were not continued in this dairy for any length of time, and the butter immediately fell off again in quality. The following letter indicates the experience of Mr. Kurt:

Dr. H. W. Conn:

DEAR SIR:—During the early summer, at a time when the quality of butter ought to have been at its best, the butter made in our dairy was very bad. In spite of every precaution in the ripening of the cream and in working the butter, there appeared streaks of curd which increased in standing, so spoiling the butter for market.

Acting on your suggestion I ripened a portion of cream with your butter culture and allowed another part to ripen as before. Two churnings were made with the following results: The part ripened with your culture yielded butter of exceptionally fine grain, and the streaks of curd had entirely disappeared; moreover, there was a marked improvement in the flavor of the butter.

The part that was ripened by itself contained the curd and was of inferior quality.

Yours truly, FRANKLIN T. KURT.

A second experiment was in the dairy of Mr. A. B. Caswell of Ashby, Mass. Mr. Caswell had been having complaints from his patrons in regard to the butter that he had been furnishing them, and requested a trial of the *Bacillus No. 41* upon his butter. A culture was furnished him in the same manner as in other experiments and he made the butter in the ordinary way. The two lots of butter which were made, one from the artificially ripened cream and the other from the normally ripened cream, showed a decided though not great difference. Both were an excellent flavored butter, but the one made from the artificial culture had in addition to the ordinary flavor the usual pleasant aroma and taste which has been found elsewhere with *Bacillus No. 41*.

The third experiment in a private dairy was on the farm of Mr. Walter Laws, Westminster, Mass. Mr. Laws had a private

dairy in which he made butter of a very high grade. In the month of September he obtained the first premium in a county fair which was held in Fitchburg, Mass. Knowing of these experiments, however, he wished to try the effect of *Bacillus No. 41* upon his butter, and a culture was furnished him and used in the usual manner. The report which he subsequently sent me was that his butter was decidedly improved by the use of the artificial culture. He continued the use of the culture for several weeks, believing that he obtained a better butter thereby. In a letter written subsequently he informed me that his butter, during the period of the use of the culture, had been better than was common at that season of the year, though whether to attribute it to the culture or to the food eaten by the cows, he did not know.

So uniform have been the results of the use of this organism that it must be regarded now as beyond the reach of experimentation, and *Bacillus No. 41* takes its rank as a species of organism whose artificial use in the ripening of cream will produce a striking improvement in the flavor of the butter. The effect of the culture upon the various grades of butter is not exactly what might have been expected, and I have been considerably surprised thereby. When the experiments were begun I had supposed it probable that the use of the artificial culture might improve a poor quality of butter, but was very doubtful whether it would have any effect, at least any advantageous effect, upon first-class butter. Experiments, however, have shown that the organism appears to be of decided value even in first-class creameries. As already mentioned, the effect of the organism appears to be to *add* to the butter an especially delicate aroma and taste, and this delicate aroma and taste is added equally to butter of a poor grade and medium grade, or to butter of the very highest quality. In the light of the present experiments, therefore, it appears that all grades of butter may be somewhat improved by the use of artificial cultures.

Another matter of some interest is the fact that *Bacillus No. 41* is not a milk-souring organism. The "ripening" of cream is in many places called the "souring" of cream, and it has been supposed by all experimenters hitherto that the souring was identical with the ripening. For this reason all of the species of bacteria which have hitherto been used in ripening cream have been acid producing organisms. Experimenters have not thought

it worth while to investigate whether or not the aroma of butter might not be due to species of organisms that do not normally sour the cream. *Bacillus No. 41*, while it produces a very slight acid reaction, does not sour the cream, and it belongs, therefore, to an entirely different class of organism from those hitherto used. This is especially interesting as indicating that probably the aroma of the butter is entirely distinct from the souring of the cream and may be produced either by acid organisms or by organisms that do not produce acid.

In one other respect *Bacillus No. 41* appears to show itself as decidedly more advantageous in practical use than the organisms hitherto used. As will be seen above no previous treatment of the cream is needed in order that *Bacillus No. 41* may produce its appropriate results. This, of course, greatly simplifies the use of the organism and makes it much more probable that artificial inoculation of cream for ripening may in the future become a somewhat universal process. So long as butter-makers are obliged to heat their cream before artificial inoculation, in order to destroy bacteria already present in it, so long will they hesitate about adopting any form of artificial inoculation. When, however, the butter can be improved from three to eighteen points by the simple addition of a culture of the proper species, the use of the organism becomes decidedly easier. When first undertaking these experiments I was extremely incredulous as to the likelihood that artificial ripening of cream would ever be very common among butter-makers. Having, however, seen what good results can accrue to all grades of butter by the simple addition of a culture to the cream, I am now prepared to believe that the artificial ripening of cream will have a growing popularity among the butter-makers of this country.

SUMMARY.

The results of the experiments with Bacillus No. 41 bring out three points of especial importance.

Bacillus No. 41 is not to be regarded as a cream-souring organism, but one whose value in ripening cream depends upon its power of adding desirable aroma to the butter.

In the use of Bacillus No. 41 no previous treatment of the cream to be ripened is necessary before it is inoculated with the culture.

Up to the present time experiments in at least sixty creameries and with some hundreds of thousands of pounds of butter have resulted in uniform improvement in the quality of the butter made from cream ripened with Bacillus No. 41.

BACTERIA IN THE DAIRY.



VII. SOME OBSERVATIONS OF THE NUMBER OF BACTERIA IN DAIRY PRODUCTS.*

BY A. E. LOVELAND AND W. S. WATSON.



NUMBER OF BACTERIA IN MILK.

Within the last few years, with the improvement of methods and the discovery that milk may serve as the medium for transporting pathogenic (disease) germs, new interest has been aroused in the bacteriological study of milk. It has been found that the milk from a perfectly healthy cow, when entirely uncontaminated, is absolutely sterile, *i. e.*, contains no germs. But ordinary milk always contains bacteria, and as milk furnishes an excellent food medium for their development, they multiply very rapidly. The presence of a large number of germs does not necessarily imply that the milk is injurious, nor does a small number of germs prove that the milk is harmless. It is not the *number* but the *character* of the germs which determine their harmfulness. It is quite possible that milk containing very large numbers of bacteria may be entirely free from harmful species, while, on the other hand, milk with only a small number of bacteria may contain disease germs.

A small number of germs may be considered as evidence of two conditions of the milk. First, it has been handled cleanly, *i. e.*, not much stable dirt has entered the pail during the process of milking, and the probability is that the milk dishes were carefully scalded; second, it may be evidence of freshness, for if the milk had stood many hours the number of bacteria would be quite large, unless the temperature of the milk is lowered so they cannot grow. With these facts in mind it will be more easily understood why milk in large cities, where it is frequently forty-eight hours old when delivered, shows large numbers of bacteria.

* These investigations were made in the Bacteriological Laboratory of Wesleyan University under the direction of Prof. Conn.

EUROPEAN INVESTIGATIONS.

In the winter of 1888-89 Dr. J. Clauss worked on the milk in Würzburg and found that the number of germs in a cubic centimeter of milk ranged from 222,000 to 2,300,000. The average was between one and two millions per cubic centimeter.*

During the same winter Knopf found from 200,000 to 6,000,000 per cubic centimeter in the milk in Munich.

Buiwid examined the milk in Warsaw, where there was an average of 4,000,000 per cubic centimeter. In the milk immediately after it was drawn from the cow he found from 10,000 to 20,000 per cubic centimeter.

In Amsterdam, Geuns found 2,500,000 per cubic centimeter in the fresh milk, but at the end of ten hours the number had increased to 10,500,000 per cubic centimeter.

Renk examined the market milk of Halle and found from 6,000,000 to 30,700,000 per cubic centimeter.

In May, 1892, Uhl studied the milk in Giessen; his thirty tests gave results from 83,000 to 169,600,000 per cubic centimeter. In the following June he found 10,500 to 13,600,000 per cubic centimeter. The average in May was 22,900,000 per cubic centimeter, but in June it was only 2,900,000. Uhl explains this difference by the supposition that the cows and stables were kept clean during this latter month, and by the additional supposition that there may have been less night's milk milked with the morning's milk.

A very systematic examination was made of more than 100 samples of the milk in Dorpat by Dr. Hugo Knochenstiern, mostly in September and October, 1892. He divided the samples into four classes according to their sources. The averages of the numbers in the several classes ranged from ten to thirty millions per centimeter.

AMERICAN INVESTIGATIONS.

But little has been done in this direction in the United States. In 1892 Sedgwick and Batchelder examined a number of specimens of milk from Boston. They found, as an average of several tests, that the milk obtained in a clean stable from a well-kept cow, by milking into a sterilized bottle, contained 530 bacteria per cubic centimeter. But when the milking was done under the ordinary conditions of farm practice, the number of bacteria

* There are 946 cubic centimeters in a quart.

reached, on the average, 30,500. From fifteen samples of milk obtained from the homes of people in the suburbs of Boston, the average was 69,000 germs; from fifty-seven samples from milkmen the average was 2,355,000; and from sixteen samples secured at groceries the average was 4,577,000 germs per cubic centimeter.

THE INVESTIGATION HERE REPORTED.

The milk used for the investigations, of which the details are given beyond, was obtained as delivered by milkmen to customers in Middletown. It was placed in a sterilized* flask and taken directly to the laboratory, where it was immediately "plated."

METHOD OF CONDUCTING THE EXPERIMENTS.

All of the apparatus was sterilized in dry heat at a temperature of 160° C. (310° F.) Distilled water, which had been sterilized by boiling on three successive days, was used for diluting.

One cubic centimeter of the milk or cream to be tested was taken in a sterilized pipette and introduced into a flask containing ninety-nine cubic centimeters of the sterilized distilled water. After this had been thoroughly shaken to insure the even distribution of the germs, another sterilized pipette was used to draw out one cubic centimeter of the diluted milk. This was inoculated into a test tube containing about one inch of gelatine culture material, which had been liquefied by placing the tube in warm water. The gelatine and diluted milk were thoroughly mixed together and then poured out on a glass plate, which rested on the surface of cold water. Before hardening, the gelatine was spread by the aid of sterilized platinum wire, into a rectangular form. The plates, after hardening, were placed in covered glass dishes and left at room temperature until the colonies of bacteria were grown. The time varied from thirty-six hours to seven or eight days. In estimating the number of bacteria, from ten to twenty fields were counted in different parts of the plate. Multiplying the average number of colonies in a square centimeter by the number of square centimeters, gave the number of colonies on a plate. This, multiplied by one hundred gave the number of colonies in a cubic centimeter of the original milk, and since each colony had grown from one bacterium, it gave the number of bacteria originally present in a cubic centimeter of the milk.

* That is, a flask which had been heated to such a temperature as to kill all bacteria present in it.

TABLE 13.
Number of Bacteria in Sweet Milk, Curdling Milk and Ripening Cream.

No.	DATE.	DILUTION.	AGE IN DAYS.	NUMBER OF BACTERIA IN ONE CUBIC CENTIMETER.*					Average.
				I.	II.	III.	IV.		
<i>Sweet Milk,</i> <i>1894.</i>									
1	February 19, -	1:50	<i>Generally 3 to 6 hours old. Less than one day.</i>	37,550	36,000	28,050	—	34,000	
2	February 19, -	1:100		44,700	36,900	36,600	—	39,000	
3	March 15, -	1:100		169,000	128,800	182,700	—	160,000	
4	April 2, -	1:100		45,000	38,000	49,400	42,300	44,000	
5	April 3, -	1:100		11,600	9,800	12,200	—	11,000	
6	April 7, -	1:100		25,800	18,500	22,400	19,200	21,000	
7	April 7, -	1:100		3,888,000	3,283,200	3,931,200	2,592,000	3,424,000	
8	June 7, -	1:200		514,800	398,800	140,400	405,000	386,000	
9	June 8, -	1:1000		6,364,000	8,415,000	11,232,000	7,797,000	8,452,000	
10	June 16, -	1:100		94,000	125,000	78,000	—	99,000	
11	June 16, -	1:100		69,000	51,000	102,000	—	74,000	
12	June 16, -	1:100		104,500	101,000	110,400	108,800	106,000	
13	June 16, -	1:100		22,400	26,300	—	—	24,000	
<i>Curdling Milk,</i>									
14	February 22, -	1:5000	3	89,280,000	84,150,000	—	—	86,715,000	
15	February 26, -	1:10000	7	227,700,000	171,000,000	198,720,000	223,280,000	207,675,000	
16	March 5, -	1:10000	7	224,460,000	265,500,000	371,250,000	207,900,000	287,302,500	
17	March 10, -	1:10000	2½	388,800,000	387,450,000	526,650,000	646,380,000	487,320,000	
18	April 10, -	1:10000	5	820,800,000	1,184,130,000	936,000,000	—	980,310,000	
19	April 11, -	1:10000	4	752,940,000	1,036,800,000	682,650,000	—	824,130,000	
20	April 12, -	1:10000	10	813,150,000	835,200,000	776,790,000	753,480,000	794,655,000	
21	April 12, -	1:10000	5	570,240,000	640,800,000	384,480,000	742,500,000	597,005,000	
22	June 10, -	1:10000	2	344,520,000	416,160,000	405,000,000	408,870,000	393,520,000	
23	June 10, -	1:10000	3	48,240,000	66,600,000	60,750,000	—	58,530,000	
<i>Ripening Cream.</i>									
24	April 5, -	1:10000	Just as collected	4,000,000	5,700,000	6,000,000	540,000	4,060,000	
25	April 7, -	1:10000	Aft. rip'ng 48 hrs	473,480,000	503,880,000	257,040,000	149,760,000	346,040,000	

* There are 946 cubic centimeters in one quart.

In table 13 it will be noticed that No. 7 and No. 9 are from the same source and give much larger numbers than the other tests. The milk in those two tests was from ten to twelve hours older than in the other samples, being night's milk while all the others were morning's milk. No. 10 is from the same source, but in that case a special request was made at the milk cart for morning's milk for examination. The result shows the difference between the morning's and the previous night's milk.

The average in the thirteen tests made is a little less than one million per cubic centimeter (990,000). But if the average is taken without including No. 7 and No. 9, which were probably night's milk, the average is reduced to less than 100,000 germs per cubic centimeter.

BACTERIA IN BUTTER.

Probably the first attempt at a quantitative estimate of bacteria in butter was made by Von Lafar at the Hygienic Institute of the University of Munich in the winter of 1890-91. He found that butter fresh from the churn contained an immense number of germs and that this number quickly fell to one or two millions or less per gram.*

In the work here reported the changes in number of bacteria in butter kept under usual household conditions have been studied. The methods employed were practically the same as those already described for milk. The butter was weighed instead of being measured and the number of bacteria were calculated per gram* instead of per cubic centimeter. Two lots of unsalted and two of salted butter obtained from the creamery as soon as made, were tested. In each instance the butter was received in pound prints and the first plates were made as soon as received. The butter was kept in an ordinary refrigerator (at 32° to 38° F.) and plates were made every few days.

The first few tests were taken from different portions of the outside of the butter roll, as the difference between the number of germs living on the outside of the butter and those living on the inside were probably slight while the butter was fresh. Later, when the difference might be appreciable, the roll was cut at various places and samples taken from as near the center as possible for the inside determination, in order to compare it with the outside.

* One pound weighs 454 grams.

TABLE 14.
Number of Bacteria in Unsalted Butter.

No.	DATE.	DILUTION.	WEIGHT.	NUMBER PER PLATE.				AVERAGE PER PLATE.	AVERAGE PER GRAM.
				I.	II.	III.	IV.		
<i>Lot A.</i>									
1.	May 1, -	-	.2941	36,288,000	34,194,000	33,660,000	31,500,000	33,910,500	115,302,000
2.	May 2, -	1:2000	.1955	8,190,000	7,722,000	—	—	7,956,000	40,696,000
3.	May 4, -	1:2000	.2615	4,080,000	3,432,000	1,980,000	1,620,000	2,778,000	10,623,000
4.	May 10, -	1:2000	.778	8,648,000	7,102,000	8,640,000	9,828,000	8,554,500	10,995,000
5.	May 15, -	1:2000	.3928	10,080,000	7,938,000	18,144,000	15,750,000	12,978,000	33,500,000
6.	May 21, -	1:2000	.5160	11,520,000	24,300,000	16,872,000	—	17,564,000	34,039,000
7.	May 25, -	1:2000	.4365	59,292,000	76,032,000	66,690,000	67,968,000	67,493,000	154,623,000
8.	May 30, -	1:2000	.219	11,160,000	13,980,000	10,350,000	11,196,000	11,671,500	53,294,000
9.*	May 30, -	1:2000	.462	256,000	314,000	306,000	276,000	285,000	618,000
<i>Lot B.</i>									
10.	May 26, †	—	—	—	—	—	—	—	—
11.	May 27, †	—	—	—	—	—	—	—	—
12.	May 29, -	1:2000	.3048	9,072,000	14,742,000	17,820,000	14,162,000	13,936,000	45,726,000
13.	June 5, -	1:2000	.5786	13,860,000	15,768,000	20,160,000	20,250,000	17,509,500	30,262,000
14.*	June 5, -	1:2000	.7689	12,551,000	13,440,000	16,560,000	18,225,000	15,194,000	19,760,000
15.	June 11, -	1:2000	.5100	5,100,000	4,418,000	6,624,000	—	5,380,000	10,551,000
16.*	June 11, -	1:2000	.5745	4,620,000	4,130,000	5,762,000	4,480,000	4,748,000	8,365,000
17.	June 16, -	1:2000	.3432	2,052,000	1,116,000	1,944,000	—	1,704,000	4,965,000
18.*	June 16, -	1:2000	.3755	1,730,000	—	—	—	1,730,000	4,805,000
19.	June 20, -	1:2000	.1960	1,581,000	525,000	540,000	567,000	801,000	4,098,000
20.*	June 20, -	1:2000	.2877	1,354,600	1,872,000	883,000	1,180,000	1,322,000	4,595,600
21.	June 21,*	1:2000	.348	17,748,000	24,426,000	29,952,000	—	24,042,000	69,086,000
22.	June 22, †	1:2000	.18	11,664,000	8,514,000	8,424,000	—	9,534,000	52,967,000

* All those marked * were taken from the interior of the butter ball; the others were all from the outer portion.

† June 21 and 22 substituted for May 26 and 27, which were lost by contamination of water.

** There are 454 grams in one pound.

No.	DATE.	DILUTION.	WEIGHT.	NUMBER PER PLATE.				AVERAGE PER PLATE.	% AVERAGE PER GRAM.
				I.	II.	III.	IV.		
<i>Lot A.</i>									
1,	May 1, -	1:2000	.7230	39,168,000	41,859,000	38,880,000	36,760,000	39,167,000	54,173,000
2,	May 2, -	1:4000	.3605	11,016,000	7,344,000	11,368,000	8,044,000	9,443,000	26,194,000
3,	May 4, -	1:2000	.6250	6,156,000	6,534,000	6,624,000	4,950,000	6,066,000	9,706,000
4,	May 10, -	1:2000	.3612	426,000	456,000	866,000	1,350,000	774,500	2,144,000
5,	May 15, -	1:2000	.4730	946,000	1,620,000	1,440,000	—	1,335,333	2,821,000
6,	May 21, -	1:2000	.3900	480,000	528,000	320,000	368,000	424,000	1,087,000
7,	May 25, -	1:1000	.3098	81,000	207,000	144,000	63,000	123,760	300,000
8,*	May 25, -	1:1000	.8079	1,728,000	1,080,000	1,035,000	990,000	1,208,250	1,495,000
9,	May 30, -	1:1000	.2705	80,000	57,000	113,000	90,000	85,000	307,000
10,*	May 30, -	1:1000	.4100	339,000	308,000	333,000	282,000	330,500	806,000
<i>Lot B.</i>									
11,	May 26,†	—	—	—	—	—	—	—	—
12,	May 27,†	—	—	—	—	—	—	—	—
13,	May 29, -	1:2000	.4038	6,000,000	9,280,000	9,072,000	8,190,000	8,135,500	20,147,000
14,	June 5, -	1:1000	.3810	1,800,000	1,932,000	1,200,000	1,932,000	1,721,000	4,517,000
15,*	June 5, -	1:2000	.4334	3,504,000	7,480,000	5,928,000	5,700,000	5,653,000	13,043,000
16,	June 11, -	1:2000	.4942	1,198,000	2,580,000	1,772,000	1,702,000	1,813,000	3,668,000
17,*	June 11, -	1:2000	.7468	2,912,000	1,560,000	2,700,000	—	2,390,000	2,201,000
18,	June 16, -	1:1000	.3877	700,000	203,000	270,000	—	391,000	1,009,000
19,*	June 16, -	1:1000	.4540	402,000	409,000	363,000	—	391,333	862,000
20,	June 20, -	1:1000	.4356	451,000	1,350,000	450,000	360,000	652,250	1,497,000
21,*	June 20, -	1:1000	.3376	510,000	460,000	350,000	406,000	431,500	1,277,000
22,	June 21,†	1:2000	.2902	12,960,000	13,320,000	9,360,000	10,800,000	11,610,000	39,196,000
23,	June 22, -	1:2000	.2750	5,100,000	9,660,000	9,000,000	6,240,000	7,500,000	27,272,700
<i>Salted Butter One Year Old.</i>									
24,	June 1, -	1:2000	.3720	20,000	44,000	48,000	50,000	40,500	109,000
25,	June 1, -	1:2000	.2681	54,000	22,000	44,000	—	40,000	149,000

* Those marked * were taken from the interior of the butter ball; the others were all from the outer portion.

† June 21 and 22 substituted for May 26 and 27, which were lost by contamination of water.

** There are 454 grams in one pound.

Tables 14 and 15, which precede, give the results of the studies made upon butter.

It will be observed that there is a constant decrease in the number of bacteria as the butter becomes older. In general this decrease is most marked at the very outset. In the case of the first lot of unsalted butter 65 per cent. of all the bacteria present died off in the first day. Ripened cream contains immense numbers of germs, hence it would be expected that freshly churned butter would also contain large numbers. After a number of days the number of bacteria are in general smaller in the inner than in the outer portions of the butter.

SUMMARY.

The number of bacteria in milk increases very rapidly with the age of the milk. This increase is most rapid when milk is kept warm, as warmth is favorable to the growth of the organisms. Cooling milk as rapidly as possible and keeping at a low temperature hinders the development of the germs.

The number of bacteria in milk as ordinarily sold may vary from thousands to millions per cubic centimeter. The smallest number found in milk sold in Middletown was eleven thousand per cubic centimeter and the largest number was nearly eight and a half millions. As there are 946 cubic centimeters in a quart, these figures mean that the milk had from ten million to eight billion (eight thousand million) bacteria per quart.

The presence of only a small number of bacteria in milk indicates care and cleanliness in its handling and storage and also that it is comparatively freshly drawn. Sour milk and ripened cream contain many millions of bacteria in a cubic centimeter.

The number of bacteria in butter, whether salted or unsalted, gradually diminishes as the age of the butter increases. In butter a year old the number becomes very small indeed. There is a more rapid decrease of bacteria in butter during the first few hours than is exhibited later and there is a more rapid decrease in the inside of the butter roll than on the outside. The decrease in salted butter is much greater in the first few hours than that of unsalted butter.

BACTERIA IN THE DAIRY.

BY H. W. CONN.



VIII. CREAM RIPENING WITH PURE CULTURES OF BACTERIA.

In the Annual Report of this Station for 1893, pp. 43-68, there were given a series of experiments upon cream ripening with a considerable number of species of bacteria which had been isolated from normal milk and cream. These experiments have been continued, with an interruption during the summer months, until the present time, and the details of the further experiments are given in the present article.

The majority of the species of bacteria which are described below, and which have been used in all of the experiments upon which the present paper is based, have been obtained from milk products. Some of them have been isolated from ripening cream from several different places in Connecticut; some of them have been isolated from sour or sweet milk; and some from fermented milk; several of them were obtained from a lot of milk which had been sent to the Columbian Exposition from Uruguay as an illustration of certain food products. A few were obtained from the air and several from water. In all cases, with the exception, therefore, of the water bacteria, the species in question may be regarded as normal milk bacteria, and their effect upon cream in its ripening and upon the butter subsequently obtained by churning the cream is, therefore, of considerable practical importance in enabling us to understand normal dairy products. The description of the species will therefore be given in more or less detail.

DESCRIPTION OF SPECIES.

No. 34.

Locality.—Isolated from the air in Jackson Park at Chicago, in August, 1893.

Morphology.—A spherical organism which has the characteristics of the genus

Merismopœdia. Size .4 μ .

Motility.—No motion.

Relation to Air.—Grows well under mica plate.

Temperature.—Grows profusely at 35° C., though not producing color. Grows also at 20°.

Colony on Gelatine.—A liquefying pit is formed with a nucleus and a cloudy edge. Differs from most liquefying colonies in not being clear round the rim, but uniformly cloudy to its extreme edge.

Gelatine Stab Culture.—Growth is abundant along the needle track. There is a slight surface growth which does not spread, is rather thick and does not very thoroughly liquefy the gelatine.

Agar-Agar.—A thick, moist layer with a sharp edge tinged with yellow.

Potato.—No visible growth.

Milk.—Is not affected either at 20° or at 35°.

Bouillon.—Becomes slightly cloudy with a tough, yellowish sediment. After four weeks liquid becomes clear.

No. 38.

This is the well-known *Bacillus subtilis*.

No. 40.

Locality.—Found in a lot of milk from Uruguay, South America, at Chicago.

Morphology.—A large micrococcus, size, .9 μ .

Motility.—Non-motile.

Relation to Air.—Will grow under mica plate.

Colony on Gelatine.—Forms a little pit with a center granular yellowish nucleus and an outer lobate granular ring. Sometimes the pit contains a yellowish granular mass without a rim. Sometimes there is formed an irregular lobate liquefying pit.

Gelatine Stab Culture.—Slow growth. Forms a narrow funnel or sometimes a deep pit which is quite dry. There is formed a thick liquid with a yellowish sediment and a yellowish scum. The gelatine never completely liquefies even after weeks of growth.

Agar-Agar.—Forms a Naples yellow, rough, dry layer with a sharp edge.

Potato.—Forms a Naples yellow, dry, mounded, thick layer, the color not so brilliant as on agar.

Milk.—After five days at 35° the milk is curdled into a soft curd with no whey. The reaction is acid. After a month it becomes much harder with yellowish flakes and there is no digestion of the curd.

Bouillon.—Remains clear with a slight, flaky scum and a slight sediment. After four weeks' growth the whole liquid clears up retaining simply a slight yellowish sediment.

No. 40 is closely allied to No. 2 described in the last Annual Report. It differs only in its ability to grow under mica and slightly in its growth in gelatine.

No. 41.

See page 57 of this Report.

No. 43.

Locality.—From specimen of Uruguay milk.

Morphology.—An oval micrococcus or a short rod not forming chains nor spores. Size, .9 μ by .7 μ .

Motility.—Non-motile.

Relation to Air.—Will grow under mica plate.

Colony on Gelatine.—A smooth, round, slightly raised white bead.

Gelatine Stab Culture.—A beaded needle track with an abundant growth. A raised, transparent surface layer which thickens into a quite thick white mass.

Agar-Agar.—A very thin, transparent, extremely tenacious yellow layer which adheres to the needle and is not easily spread or diffused through water.

Potato.—No visible growth.

Milk.—No noticeable effect upon milk. After several weeks there is a slight acid reaction in the milk, but not sufficient to curdle the milk when heated.

Bouillon.—Liquid becomes uniformly cloudy with a dense, tough, yellowish sediment. After four weeks the liquid clears retaining the sediment.

No. 44.

Locality.—Milk from Uruguay.

Morphology.—A large micrococcus 1.5μ in diameter.

Motility.—Non-motile.

Relation to Air.—Will grow under mica plate.

Temperature.—Grows well at 35° and at 20° .

Colony on Gelatine.—A smooth, round, raised gray colony. Sometimes there is formed a whitish bead at first which spreads into a grayish colony of small size.

Gelatine Stab Culture.—There is an abundant needle growth with a thin, transparent, slightly spreading surface growth. Sometimes in old cultures the surface is sunken into a dry pit.

Agar-Agar.—A thin, whitish, dry iridescent growth, rather tough and not dissolving in water.

Potato.—A yellowish or slightly brown growth turning the potato dark colored.

Milk.—No change in the milk although after a couple of months' growth the milk becomes rather thick and transparent. Reaction is hardly affected.

Bouillon.—A uniformly cloudy liquid, especially cloudy at the surface, where there is a thick cloudy layer of considerable depth, but no true scum. After four weeks the liquid is still cloudy with a slight scum.

No. 45.

Locality.—From Chicago. Isolated from a lot of fermented milk (Matzoon). The milk had a pure, clean, sour taste and a fine curd.

Morphology.—A species of *Sarcinina*, $.7 \mu$ in diameter.

Motility.—Non-motile.

Relation to Air.—Grows under mica plate.

Temperature.—Grows abundantly at 35° , producing abundant culture. Grows well at 20° .

Colony on Gelatine.—A large, slightly sunken colony, with a nucleus and granular edge.

Gelatine Stab Culture.—Slight growth along needle track, forming a yellowish dry layer on the surface of the gelatine.

Agar-Agar.—A bright, yellow raised layer with sharp edges and not very diffusely spreading.

Potato.—Very slight growth on potato, with a slight yellowish tinge.

Milk.—No effect on milk at any temperature.

Bouillon.—The liquid remains clear, but a sediment appears and also flakes arise on the sides of the tubes. These flakes continue to make their appearance and sink to the bottom for some time. After four weeks the liquid is clear, with a distinct sediment.

No. 46.

Locality.—From Matzoon, at Jackson Park, Chicago.

Morphology.—A short rod which forms chains of two or sometimes more. Size, .8 by .4 μ on agar; slightly smaller on potato.

Motility.—Possesses motion.

Relation to Air.—Will grow under mica plate.

Temperature.—Grows well at 35°, producing its color. Grows also at 20°.

Colony on Gelatine.—A pit is formed with a rough crenate mass at the center. It spreads rapidly, becoming granular, and finally forms a pit with a nucleus and a clear rim.

Gelatine Stab Culture.—An abundant needle growth is formed at first, and then a shallow pit at the surface, which slowly deepens, and after about eleven days forms a layer of liquefied gelatine half an inch deep.

Agar-Agar.—A very thin, white, smooth layer which subsequently becomes yellowish.

Potato.—A thick growth which is of a bright lemon yellow color.

Milk.—The milk is very slowly affected. After about three weeks it is curdled into a soft mass which is either weakly alkaline or amphoteric in reaction. After six weeks' growth it becomes slightly brown, and if kept at 35°, eventually is almost completely digested into a transparent brownish liquid which finally becomes almost mahogany colored. If the organism is cultivated at 35° for nine days and is then heated to a boiling temperature, the milk curdles.

Bouillon.—Liquid becomes very cloudy, with a yellow precipitate forming. After four weeks it still remains cloudy with a dense precipitate.

No. 47.

Locality.—From the air at Middletown.

Morphology.—A small micrococcus .4 μ in diameter.

Motility.—None.

Relation to Air.—Does not grow under mica plate.

Temperature.—Grows profusely at 35°.

Colony on Gelatine.—A small, round, smooth, raised, snow-white bead.

Gelatine Stab Culture.—An abundant growth along needle track with a thick, moist, but not widely spread surface growth.

Agar-Agar.—A very moist, almost watery snow-white growth not very widely spreading.

Potato.—Very watery, spreading over the surface of the potato. Snow white.

Milk.—No effect upon the milk except a slight increase in alkalinity after about three weeks. At 35° there is sometimes a slight increase in thickness of the liquid.

Bouillon.—A uniformly cloudy liquid rather clear at the surface. After four weeks the whole liquid clears up with a sediment.

No. 48.

Organism No. 48 is almost identical with *Bacillus erythrogenes*. It differs from the latter only in producing no growth on potato and in producing a brownish red rather than a blood-red milk.

No. 49.

Locality.—Air from Middletown.

Morphology.—A large micrococcus $1\ \mu$. in diameter.

Motility.—None.

Relation to Air.—Does not grow under mica plate.

Temperature.—Grows very slowly at 35° . Color not well developed at this temperature.

Colony on Gelatine.—Not characteristic.

Gelatine Stab Culture.—Slight needle growth and a slight superficial growth which is orange colored.

Agar-Agar.—A very thick dark orange growth which is quite transparent.

Potato.—No visible growth.

Milk.—No effect on milk at any temperature.

Bouillon.—A uniformly slightly cloudy liquid, which clears up after four weeks with a sediment.

No. 51.

Locality.—Ripened cream from Durham, Conn.*

Morphology.—A large rod in long chains. Rods with square ends, forming large spores in the middle. Size, 1.5 to .2 by $.8\ \mu$. When growing on agar the chains break up into short rods.

Motility.—None.

Relation to Air.—Will grow under mica plate, but not much except near the edge.

Temperature.—Grows rapidly at 35° , less rapidly at 20° .

Colony on Gelatine.—A slight liquefying colony forming peculiar characteristic contorted masses with the threads arranged in parallel rows. Colony very much like that of *Proteus*. Very characteristic.

Gelatine Stab Culture.—Growth is slow. A shallow pit is formed which, after two or three weeks, liquefies about half an inch of gelatine. The pit is always cone shaped and liquefaction never proceeds very far even in the oldest cultures.

Agar-Agar.—An abundant, spreading growth, quite dry and granular, and having somewhat the appearance of ground glass.

Potato.—A dry, velvety white, sometimes even snow-white growth, becoming very thick.

Milk.—Curdles in two days into a soft, jelly-like mass which is weakly alkaline and is rapidly digested into a cloudy, yellowish liquid with an abundant sediment. The final digested mass is distinctly alkaline.

Bouillon.—A clear liquid with a scum forming at the surface which sinks in flaky masses when disturbed.

No. 52.

Locality.—Cream from Cromwell.

Morphology.—A minute micrococcus $.3\ \mu$ in diameter forming chains which have a tendency to arrange themselves into rings.

Motility.—Non-motile.

* A variety of the same species has been found in snow in Middletown, Conn.

Relation to Air.—Will grow under mica plate.

Temperature.—Grows rapidly at both 20° and 35°.

Colony on Gelatine.—A smooth, round, raised white colony which reaches the diameter of 1 mm. Colony very white and not spreading.

Gelatine Stab Culture.—A typical nail culture with an abundant needle growth and a snow-white, thick, raised, round surface growth.

Agar-Agar.—An abundant, thick, smooth, glistening white growth.

Potato.—Very abundant growth spreading over the potato, quite thick and snow white.

Milk.—Curdles at 35° in three days; at 20° in six days. Curd is soft and acid and has the odor of ordinary sour milk.

Bouillon.—Uniformly cloudy growth with a slight sediment.

No. 53.

Locality.—Milk from Middletown.

Morphology.—A short bacillus.

Motility.—None.

Relation to Air.—Grows slightly under mica.

Temperature.—Grows well at 20° or at 35°.

Colony on Gelatine.—A large raised bead which spreads over the surface as a white, smooth colony 1 mm. in diameter.

Gelatine Stab Culture.—Abundant needle growth, somewhat granular. Surface growth is abundant, somewhat spreading, pearly white and waxy. Abundant gas bubbles produced in the gelatine.

Agar-Agar.—An abundant, thick, raised white growth, not specially characteristic.

Potato.—A white growth tinged with brownish, quite abundant, usually thick, though sometimes thin and spreading where potato is very moist.

Milk.—Curdles in two to three days at a temperature of 20°. Is very acid. Curd is hard with a little whey, and does not digest.

Bouillon.—Slightly cloudy bouillon with a slightly thick precipitate.

No. 54.

Locality.—Milk from Middletown.

Morphology.—

Motility.—None.

Relation to Air.—Will grow under mica plate.

Temperature.—Grows at 37° and also at the temperature of the room.

Colony on Gelatine.—A large surface colony, irregular or lobate in outline, white.

Gelatine Stab Culture.—Slight needle growth or a thin, irregular surface growth.

Agar-Agar.—Whitelayer not especially characteristic.

Potato.—

Milk.—Does not curdle at temperature of the room in seven days, but the milk becomes distinctly acid. Becomes slightly thick with a clear stratum on top.

Bouillon.—Cloudy bouillon with white precipitate.

This organism was lost before its characters were completely determined.

No. 55.

Locality.—Milk from Middletown.

Morphology.—A short rod with rounded ends. Size, 1 by .8 μ . Contains clear bodies which look like spores.

Relation to Air.—Grows under mica.

Motility.—Non-motile.

Temperature.—Slight growth at 35°.

Colony on Gelatine.—Colonies below surface round and small. Surface colonies spread into good-sized white, slightly granular colonies. They are white with smooth contours.

Gelatine Stab Culture.—Slight growth along needle track. Surface growth is thin, semi-transparent and spreading.

Agar-Agar.—White growth which is not characteristic.

Potato.—Thick, spreading, irregular contoured growth which is slightly lemon color.

Milk.—No effect except a slight transparency.

Bouillon.—A clear liquid shows a flaky precipitate.

No. 56.

Locality.—Milk from Middletown.

Morphology.—Bacilli with rounded ends. In pairs but no chains. Size, 1.2 μ by .8 μ .

Motility.—Non-motile.

Relation to Air.—Grows under mica plate.

Temperature.—Grows at 20° also rapidly at 35°, with wrinkled surface.

Colony on Gelatine.—Surface colonies large, white, thin and transparent. They are irregular and lobate in outline and with irregular surface.

Gelatine Stab Culture.—Surface growth is clear, irregular edged and thin. An abundant granular needle track growth.

Agar-Agar.—Thin, white, spreading. If the agar is dry the growth does not spread but shows parallel rows of colonies on each side of inoculation line.

Milk.—Milk becomes very acid but does not curdle.

Bouillon.—Slightly cloudy with white sediment.

With the organisms above described experiments upon cream ripening have been carried on for the last eight months. In all there have been about 200 of these experiments up to the present time. The experiments have been identical with those described in the Annual Report* of a year ago, and each experiment was conducted as follows: A small lot of milk was passed through a separator, and the cream obtained therefrom was divided into two lots and placed in two sterilized cans. Both lots were then pasteurized in hot water at a temperature of 69° C. (156° F.) Into the pasteurized cream was poured about 25 cubic centimeters of a milk culture of one of the organisms to be experimented on. The two lots were always inoculated differently in order that a

* Sixth Annual Report of this Station, 1893, pp. 43-60.

careful comparison may be made. Sometimes one was inoculated with one species and the other with another. Sometimes one was left without inoculation for control. The inoculated cream was then allowed to ripen at varying temperatures and for varying lengths of time. The temperatures which have been adopted have been 20° C. (68° F.) and 24° C. (75° F.), and the length of ripening has been usually 24 hours, though in some cases 48 hours. After the ripening a careful examination of the ripened cream was made, the cream was churned and the butter also carefully examined as to taste and flavor, both with and without salting. With each of the organisms above described several experiments have been performed, in most cases eight to ten, and in all cases enough to bring about uniform results. Where a half dozen experiments followed each other with absolutely uniformity the organism in question was no longer experimented with, but another was taken. But whenever any lack of uniformity arose in the results of the first half dozen experiments, the experiments with the organism were continued until absolute uniformity was reached. In this way the effect upon the butter of ripening the cream with each organism was determined accurately. In the following descriptions it is not thought necessary to give the details of each of these experiments. Most of the 200 are duplicates of each other, and the essential results can be given just as well by describing a few experiments as by describing them all. It will be, of course, understood that in the following descriptions we have results which have been confirmed in every case by a series of experiments, and in no cases are the results of experiments isolated ones. They may, therefore, be regarded as accurate so far as this method of experimenting with pasteurized rather than sterilized cream makes accuracy possible.

Species No. 34.

At a temperature of 20° for 24 hours or 36 hours the cream is scarcely changed. It remains thin and limpid, although it acquires a very slight acid reaction and a slight sweet taste. The butter made from it is good, but mild. It shows no decided flavor and lacks the desirable aroma present in properly ripened butter. It is, indeed, very similar to butter made from unripened cream. No. 34 is, therefore, a neutral species whose presence in normally ripened cream will have no great influence.

Species No. 38.

As will be noticed from the above description, No. 38 is the common *Bacillus subtilis*, an organism which is well known and abundant in and around barns and dairies. It is, therefore, of especial interest to notice the effect of this organism upon the ripening of cream and the flavor of the butter. For that reason a larger number of experiments were performed with No. 38 than with most of the others, and the experiments were practically uniform in their results. The cream under its influence was thickened, the amount of the thickening depending upon the length of ripening and the temperature. At 20° C. (68° F.) for 24 hours the cream was only slightly thickened as a rule, while, if ripened for a few hours longer, or if inoculated with a larger culture, the cream became quite thick, but not properly curdled. The reaction of the cream remained practically unchanged, the cream being essentially amphoteric, like normal fresh milk. There was noticed scarcely any change in the odor of the ripened cream, and it had hardly any appreciable taste. The peculiar flavor of fresh cream, however, had disappeared, and no prominent flavor or odor appeared in its place. The cream usually churns with considerable difficulty, and the butter made therefrom is poor in quality. There is no decidedly disagreeable taste unless the cream is over-ripened, but the action of this species seems to take away the somewhat pleasant flavor of the sweet cream which would ordinarily produce a delicate flavor of sweet cream butter. Although sweet cream butter is usually regarded as rather a tasteless product, it does have a slight and to many agreeable flavor. *Bacillus subtilis* completely destroys this delicate flavor and leaves the butter almost absolutely tasteless. It makes butter which is much inferior to that of sweet cream butter, because it takes away from the butter even the slight taste which it would have had without the ripening. *Bacillus subtilis* is, therefore, a species that is distinctly objectionable in ripening cream, and if present in any considerable quantity will result in a deterioration of the flavor and the quality of the butter. When, however, it is present in small quantity it probably will have no especial influence, because it has no decided flavor of its own, and if other organisms are present with it to give a proper flavor, *Bacillus subtilis* will probably produce no objectionable results.

Species No. 40.

The cream becomes slightly thickened at the end of 24 hours. If the ripening is continued for 48 hours it becomes decidedly thickened, or if ripened at a higher temperature than 25° C. (77° F.) The reaction is neutral, or if the ripening is continued it becomes slightly acid. It possesses a very slight, indescribable odor with practically no taste, the taste of the ripened cream being almost the same as that of the fresh sweet cream. The cream churns readily and produces a butter which is usually of a good grain, though occasionally soft and fluffy when the ripening is carried too far. The flavor of the butter is good, although not first-class. The specially desired butter aroma seems to be wholly absent. This species may be regarded, then, as a neutral species having no noticeable effect upon the butter, either in producing a good or a bad flavor. If present in ripening cream its influence will be inappreciable.

Species No. 41.

This species is more fully described elsewhere in this Report* and need not be mentioned again here.

Species No. 43.

This species is a neutral one. Only a few tests were made with it, but in these hardly any effect upon the butter was noticed. The butter was mild and possessed hardly any flavor.

Species No. 44.

A moderate temperature, either 20° C. (68° F.) or 23° C. (73° F.) for 24 hours, produces no appreciable effect upon the cream. It neither thickens nor changes its reaction, nor its flavor nor taste. The butter made from it is extremely mild and almost like sweet cream butter. When the cream is ripened at a higher temperature, or for 48 hours, it becomes quite thick and smooth, acquires an acid reaction with a sour but pleasant taste and produces butter which is good but very mild, and with no very prominent taste. No. 44 is thus like No. 40, a purely neutral species whose effect upon the cream is very slight indeed, and its effect upon the butter is so slight as to be inappreciable. It would have no influence upon butter, either for good or for bad, if present in the normally ripening cream.

* This Report, pp. 57, 58.

Species No. 45.

This species produces slight changes in the cream. If ripened at 23° C. (73° F.) for 24 hours, or at 20° C. (68° F.) for a longer period, the cream becomes slightly thick with a slight acid reaction. There is no appreciable odor, but there is rather of a pleasant, though sweetish taste. The taste is not just like sweet cream, but is quite distinctly sweet. The butter made therefrom is tolerably good butter, with very little flavor to be noticed. The flavor is too mild for first-class butter, and yet the butter would always be regarded as of a good quality. When the ripening is allowed to continue for two days, or at a higher temperature, the flavor still remains good, but the butter is apt to be soft and of a poor grain. No. 45, therefore, is a species which may be of some advantage in the ripening of cream, but will not of itself produce a proper butter flavor.

Species No. 46.

This species produces a thickening of the cream which may be considerable if the ripening is carried to a little more than the ordinary limits. The reaction is slightly acid. There is very little change in the taste and flavor of the cream, although a very slight sweetish taste is noticed and an odor a little different from that of fresh cream. The butter is very apt to be poor in grain and is practically tasteless. This species is, therefore, another neutral species which neither has any good nor specially injurious influence upon the cream. It is not a species which has any distinct relation to the phenomena of cream ripening.

Species No. 47.

This species produces a slightly thickened cream with an alkaline reaction. There is a peculiar, though indescribable odor, with a sweet, pleasant taste. The butter is good, quite hard and fine-grained. It is rather mild, although of a good flavor. The ripening may be carried on at a temperature as high as 28° C. for 24 hours without injury, or at 20° C. (68° F.) for 48 hours and not be over-ripened. This species is, therefore, one which may be of value in butter-making, and seemingly is one of those that directly contributes toward producing a good flavor. By itself, however, the proper aroma is hardly developed, the butter being too mild even when ripened for a long time.

Species No. 48.

Cream is very slightly thickened. Indeed, in some cases there is hardly any appreciable change in the appearance of the cream after ripening, even at a temperature as high as 28° C. When, however, the ripening is continued for a longer time the cream becomes thickened. The reaction is alkaline or amphoteric, and, hardly changed from the normal reaction of the milk. There is a very slight, not especially pleasant, odor developed and a peculiar, sweet taste. The butter made from the cream has in every experiment a peculiar taste as if the cream had been over-heated in pasteurization. It was thought at first that this was due to over-heating, but the absolute uniformity with which this flavor appeared led to the conclusion that it was really a taste produced in the cream by the action of the organism itself. The butter was not good and would have been everywhere regarded as very poor in quality. No. 48, therefore, is an unfavorable species for butter-making. Although producing a good grained butter, from a cream which churns quickly, there is a tendency to give to the butter an unpleasant flavor which makes the organism injurious for normal butter-making.

Species No. 49.

By this organism the cream is slightly thickened into a smoothish mass which is alkaline or amphoteric in reaction. There is only a very slight flavor, but a sweet, pleasant taste in the cream. The butter made therefrom is of an excellent quality. It is not so good as that produced by No. 41 and yet has a pleasant, agreeable flavor and a good grain. It may be regarded, therefore, as one of the species of organisms advantageous to butter-making.

Species No. 51.

Cream is rendered somewhat thick and smooth by the action of this species when used for 24 hours at 20° C. (68° F.) The reaction is hardly changed. A peculiar, indescribable odor is noticed and a sweet, very pleasant taste to the cream. The butter made therefrom is mild, tolerably good in taste, though never producing a typical aroma such as desired in first-class butter. It is a species whose presence in the cream is of no special importance either in producing good or poor butter.

Species No. 52.

When ripened at ordinary temperatures and for ordinary length of time the cream remains thin although it becomes filled with bubbles of gas indicating the probable formation of carbon dioxide. If the temperature is raised the gas is more abundant and the cream becomes thicker. The reaction is acid when the ripening takes place in a typical fashion. The odor is that of typical sour milk or sour cream and the taste the same. The butter made therefrom is good with a slight acid flavor. The aroma is not developed but the butter has the acid flavor which is desired as one of the factors of a high quality butter. This organism is, therefore, one of the better species of cream bacteria and undoubtedly aids in producing a proper cream ripening and butter flavor.

Species No. 53.

This organism makes the cream more or less thick according to the length of the ripening, and produces an abundant gas. When the cream that has been ripened with No. 53 is agitated the gas rises in a mass of bubbles to the surface and sometimes collects in a froth. The cream is curdled if the ripening continues long enough. It is decidedly acid and has the well-known typical odor of sour milk. The taste is also like that of sour milk. Butter made therefrom possesses a moderate acid flavor which may be decidedly too acid if the ripening continues too long. There is not produced, however, any proper butter aroma, and although the butter is tolerably good it is not first-class butter from lacking the especially desirable character of high quality product.

Species No. 54.

No. 54 has very little effect upon the appearance of the cream unless the ripening is continued for a long time. The cream remains thin, no gas is produced, but it is rendered decidedly acid and acquires a peculiar, penetrating, rather strong odor, somewhat resembling garlic. The butter made therefrom is never of very good quality, although in some cases when the ripening has not been carried too far the butter is tolerably good. It is, however, never possessed of a proper butter aroma and usually has an unpleasant taste. The species is an unfavorable one for butter-making.

Species No. 55.

No. 55 has no appreciable effect upon the appearance of the cream. The cream remains thin and develops no gas. The cream is rendered slightly alkaline and possesses a peculiar, vile odor, which is sometimes decidedly strong and unpleasant. The taste is also bad and the butter made therefrom, though not having so strong a taste as the cream, is never good. There is no butter aroma; there is no acid taste and what taste there is, is an unpleasant one. The species is an unfavorable one for the butter-maker.

Species No. 56.

This organism produces an acid cream which is sometimes thickened if the ripening continues for a proper time, but if continued only a day the cream is quite thin. No gas is developed, but there is a strong, penetrating, pungent, or sometimes musty odor, and an unpleasant taste. The butter made therefrom is always poor. It does not have a very strong odor, but is usually of rather a brackish or sickish taste and lacks any desirable butter aroma.

In addition to the organisms above described, six other species of bacteria have been isolated from water by Dr. K. C. Mead, and with these organisms experiments in cream-ripening have been made. Without going into the details of the descriptions of the organisms, the results of their action upon butter may be noted as follows:

No. 1 produced butter with practically no taste and poor grain. No. 5 produced butter with a strong odor and taste of decay, the butter giving a slight indication of putridity; the cream was extremely vile in taste and flavor. No. 6 produced butter that was quite good but mild, and with a flavor that was not typical; it produced hardly any effect upon the cream and very little effect upon the butter. No. 7 produced butter which is essentially tasteless when the cream is ripened normally, or if the cream is over-ripened the butter is decidedly sour. No. 7 produced butter with a tolerably good grain, but with very little taste. The taste, however, was not bad except when over-ripened. The cream was hardly changed in its appearance or its reaction, and has very little odor or flavor. This species produced no good or ill effect upon the butter. No. 8 has a slight thickening effect upon the cream and gives rise to a good grained but absolutely tasteless

butter. It is worse than No. 7, the flavor being inferior to that made from sweet cream.

These experiments are still in progress, and it appears best to defer a summary and discussion of them until a later period when other experiments can be published in detail. It may perhaps be well, however, to notice the relation of the species experimented with up to this time to the power of producing lactic acid. The phenomena which is in this vicinity called "ripening" is frequently called "souring," and is practically always accompanied in normal butter-making by the production of lactic acid. It will be seen, however, from the various experiments already published, that the souring of the cream is only one of the phenomena, and that the production of a proper butter flavor is dependent upon some changes entirely independent of the formation of lactic acid. The fact that in some cases the bacteria do not produce the same reaction in the cream as in sterilized milk is doubtless due to the uncertainties of pasteurization. Of the 29 species of bacteria whose effect upon butter has been described in this paper and in the previous report, 10 produce acid in milk and cream, and therefore sour the cream, viz.: Nos. 5, 16, 16*i*, 18, 20, 21, 40, 52, 54, and 56. Of these only two make what has been regarded as *good* butter, viz.: Nos. 16 and 52. Five have been found to make milk and cream slightly acid without souring it to any noticeable degree, viz.: Nos. 34, 41, 44, 45, 46. Of these two, Nos. 41 and 45 produce *good* butter. Twelve either have no effect on the butter or render it slightly alkaline, viz.: Nos. 2, 22, 27, 19, 26, 31, 38, 47, 48, 49, 51, and 55, and of these four produce *good* butter, viz.: Nos. 2, 22, 47 and 49. On the other hand, at least four of the acid species produce decidedly *bad* butter, Nos. 16*i*, 18, 54, and 56, and of the species producing an alkaline reaction five produce *bad* butter, Nos. 27, 31, 38, 48, and 55. All of the other species produce little or no appreciable effect on the butter. Of all the species thus far studied, the one producing the best results and the most desirable aroma in the butter was No. 41, which, while producing a little acid, does not appreciably sour the milk or cream and never either curdles it or even renders it thicker than usual. The experiments, therefore, thus far indicate that the butter aroma has nothing to do with the production of lactic acid.

FEEDING EXPERIMENT WITH SHEEP.

BY CHAS. D. WOODS AND C. S. PHELPS.

The experiment was undertaken in order to observe the effects of different kinds of food upon the chemical composition of the flesh of sheep, and is a continuation of that reported in the preceding Report* of this Station.

PLAN OF THE EXPERIMENT.

The plan consisted in selecting a number of sheep of the same breed and age, and as nearly alike as possible, and dividing them into four groups. One group was to be butchered at the beginning of the experiment and the flesh analyzed. The results of the weighings and analyses of this group would serve to indicate more or less accurately the condition of the other animals at the beginning of the experiment. Two other groups were to be fed differently, one upon a wide ration (relatively deficient in protein), the other upon a narrow ration (relatively rich in protein). In the two groups just mentioned, each animal was fed in a separate pen. A fourth group was selected from the remainder of the flock and fed collectively in one pen. This group received the narrow ration. The main object of this part of the test was to observe whether there would be any advantage in feeding in groups rather than in single pens adjoining each other. At the end of the experiment the animals were all to be butchered and as complete analyses of the flesh made as should seem advisable.

DETAILS OF THE EXPERIMENT.

About the middle of October, 1893, a flock of 38 grade Shropshire lambs of the preceding spring were purchased for the experiments of the winter of 1893-94. They were bred and reared in Vermont by one farmer, and were in medium condition when purchased, although they varied considerably in size. The smallest were excluded from the experiment. The animals were kept in a yard, covering about one-fourth of an acre, and were fed, in addition to the pasturage of the yard, early-cut hay till Nov. 8. At this time they were divided into groups.

* Report of this Station, 1893, pp. 28-42.

Four average animals of quiet dispositions were first selected for digestion experiments on the rations to be fed in the feeding experiments with the other animals. Three groups of five each were then selected for the feeding experiments. Lot A of five, Nos. 13-17, was placed in a large pen preparatory to slaughtering. Two other lots of five each—B, Nos. 20-24, and C, Nos. 25-29, were placed in individual pens. They were fed alike till Nov. 14, being allowed all the good hay they would eat, and each in addition had about one-half pound of ground oats and peas.

Beginning Nov. 14, each animal was allowed 12 ounces of ground oats and peas and $1\frac{1}{2}$ pounds of early-cut hay. On Nov. 16, all of the lambs of lots A, B and C were weighed and individuals were shifted until the total weights for each lot were nearly the same.

Six animals of about the same total weight as the other lots of five each, were also selected from the remainder of the flock and placed in a large pen to be fed collectively. The experiment began Nov. 16. Lot B was fed the wide ration and lot C and the group (D) had the narrow ration. The following table gives the weight of each animal at the beginning of the experiment and the total and average for each lot:

Weights of Each Sheep and Total and Average Weight of Each Lot at Beginning of the Experiment.

LOT (A) SLAUGHTERED.		LOTS FED IN SINGLE PENS.				GROUP (D) FED.	
Nos.	Nov. 16.	Wide Ration, Lot B.		Narrow Ration, Lot C.		Narrow Ration.	
	Lbs.	Nos.	Lbs.	Nos.	Lbs.	Nos.	Lbs.
13	79.0	20	59.5	25	61.5	30	58.0
14	60.0	21	75.5	26	55.8	31	48.5
15	54.5	22	55.5	27	71.3	32	46.0
16	54.5	23	59.0	28	50.5	33	63.0
17	56.0	24	56.0	29	63.5	34	45.5
—	—	—	—	—	—	35	44.0
Total,	304.0	—	305.5	—	302.6	—	305.0
Average,	60.8	—	61.1	—	60.5	—	50.9

From this tabulation it will be seen that the total weights of each lot were essentially the same, and that the average weights of the sheep in each lot, except the group, were nearly alike.

The sheep of the group (D) fed collectively were considerably smaller than those of the other lots, six animals weighing about the same as five in each of the other lots. It will be noticed that the individual sheep of each of the lots varied considerably. This was an unfortunate condition, as it probably indicated somewhat similar differences in the general vigor and thriftiness of the sheep.

The five animals intended for slaughter (Lot A) were killed Nov. 16, and were intended to represent as nearly as possible the average condition of the other three lots. The feeding commenced Nov. 16 and continued till March 29 for the two lots (B and C) fed singly, and till April 13 for the group (D). The sheep fed in single pens were separated from each other by only slat partitions, and they seemed quiet and contented throughout the experiment.

TABLE 16.

Kinds and Amounts of Food in Ration Used for Each Animal in Sheep Feeding Experiment, 1893-94.

KIND OF FOOD.	FED FROM NOV. 16 TO MARCH 29, 133 DAYS.		GROUP D.
	Each Day.	Total for 133 Days.	Daily.
<i>Lot A.</i>			
<i>Sheep Nos. 20-24, Wide Ration.</i>			
	Oz.	Lbs.	
Corn meal, - - - - -	12	100	—
Wheat bran, - - - - -	4	33	—
Hay, - - - - -	16	133	—
Turnips,* - - - - -	4	11	—
	36	277	—
<i>Lot B, and Group Lot D.</i>			
<i>Sheep Nos. 26-29, and Nos. 30-35, Narrow Ration.</i>			
Linseed meal, 3 parts, } mixture, - - -	4	33	20
Corn meal, 1 part, }			
Oat and pea meal, - - - - -	8	67	40
Wheat bran, - - - - -	4	33	20
Hay, - - - - -	16	133	80
	32	266	160

* Fed 44 days; Feb. 10 to March 26.

KINDS AND AMOUNTS OF FOOD.

As the animals varied considerably in weight, it was thought best to feed each sheep according to the requirements of its appetite. The sheep were fed on about the same plan as in the experiment of the winter of 1892-93.* Those of the wide ration

* Report of this Experiment Station, 1893, page 28.

(lot B, Nos. 20-24) were fed hay from early-cut mixed grasses, together with corn meal and wheat bran, with a small amount of turnips, during the latter part of the experiment. Those having the narrow ration (lot C, Nos. 25-29) received the same kind of hay, and in addition, corn meal, wheat bran, linseed meal, and ground oats and peas. The group (D) was fed the same kinds of feed as lot C. Two rations, assumed to be normal in quantity, one wide and one narrow, were first prepared and taken as a basis, the total amounts fed being increased or decreased from time to time according to the appetites of the sheep.

Sheep No. 24 of the wide ration and No. 25 of the narrow ration were dropped out during the latter part of the experiment owing to lack of thriftiness, so that the discussion which follows applies to only four sheep in lot B and four in lot C. The amounts fed in the normal ration are shown in table 16 on the opposite page.

TABLE 17.

*Percentage Composition of the Feeding Stuffs Used and the Uneaten Residues in Sheep Feeding Experiment of 1893-94.**

MATERIALS FED.	Water.	Protein.	Fat.	Nit.-free Ext	Fiber.	Ash.
	%	%	%	%	%	%
Corn meal, - - - -	12.42	10.10	4.54	70.43	1.28	1.24
Wheat bran, - - - -	8.90	17.34	5.23	52.95	9.91	5.67
Linseed mixture, - - -	10.50	30.06	5.53	43.60	5.96	4.35
Oat and pea meal, - - -	11.55	23.88	2.53	52.05	6.62	3.37
Hay (mixed grasses,) - - -	8.31	11.18	3.59	40.65	31.04	5.23
<i>Uneaten Hay Residue.</i>						
Sheep No. 20, - - - -	9.25	11.13	3.20	44.14	26.33	5.95
Sheep No. 21, - - - -	7.56	9.31	3.12	45.94	28.95	5.12
Sheep No. 22, - - - -	7.95	11.25	3.41	48.23	23.52	5.64
Sheep No. 23, - - - -	7.37	10.38	3.91	46.33	26.34	5.67
Sheep No. 26, - - - -	8.61	11.38	2.75	48.60	23.32	5.34
Sheep No. 27, - - - -	7.69	12.69	3.03	45.01	26.54	5.04
Sheep No. 28, - - - -	9.08	14.81	2.68	44.18	24.50	4.75
Sheep No. 29, - - - -	9.09	14.25	2.42	40.11	29.52	4.61
Group D, - - - -	8.21	13.25	2.49	39.95	30.36	5.74
<i>Uneaten Grain Residues.</i>						
Sheep No. 20, - - - -	10.49	12.38	3.17	61.99	6.26	5.71
Sheep No. 22, - - - -	8.41	12.31	3.59	64.84	6.71	4.14
Sheep No. 23, - - - -	8.57	11.75	3.92	64.32	5.30	6.14
Sheep No. 26, - - - -	8.32	21.38	2.75	45.57	16.19	5.79
Sheep No. 27, - - - -	8.01	20.75	2.62	49.86	13.31	5.45
Sheep No. 28, - - - -	8.87	22.63	2.75	47.98	12.11	5.66
Sheep No. 29, - - - -	9.42	21.56	2.38	47.37	13.21	6.06
Group D, - - - -	8.89	19.06	3.32	46.79	13.70	8.24

* For composition of these feeding stuffs calculated on water-free basis, see pp. 23-25 of this Report.

PERCENTAGE COMPOSITION OF THE FEEDING STUFFS USED.

Samples of the grain and hay fed in the experiment were selected from time to time for the purpose of learning the composition of the feeds used. These were taken in connection with the digestion experiments, two of which were made on the "narrow" and two on the "wide" ration. The uneaten residues of each animal were also kept separate, the residue of grain being separated from the hay as far as possible.

The composition of the feeds used, and of the residues, is shown in Table 17, which precedes.

DIGESTIBILITY OF THE RATIONS.

In the sheep-feeding experiment of the winter of 1892-93 the digestibility of the rations was calculated from average coefficients of digestibility of the different fodders, taken largely from the results of American experiments, and in a few cases from German experiments. The digestibility of the fodder is one of the most important factors which bear upon its effect on the animal, whether fed for growth, fattening, or milk. Any one fodder is liable to vary widely in digestibility from the average given in tables of compilations, so that even if the feeds used are analyzed, a source of error is introduced unless the digestibility of the particular ration is also known.

Two digestion experiments were made on both the narrow and the wide ration, two sheep being used in each case. The details of these digestion experiments are given in the papers on digestion experiments with sheep which follows this article.

The percentage digested of each of the constituents of the rations is shown in the following tables:—

TABLE 18.

RATIONS FED DAILY.		Organic Matter.	Protein.	Fat.	Nit.-free Ext	Fiber.	Ash.
<i>Wide Ration.</i>							
Corn meal,	- - - 12 } Oz.	69.0	55.0	68.5	76.4	55.3	23.0
Wheat bran,	- - - 4 }						
Mixed hay,	- - - 16 }						
<i>Narrow Ration.</i>							
Corn meal,	- - - 1 }	71.6	73.4	70.5	74.8	62.5	29.2
Linseed meal,	- - - 3 }						
Wheat bran,	- - - 4 }						
Oat and pea meal,	- - - 8 }						
Mixed hay,	- - - 16 }						

It will be readily seen that the narrow ration (relatively rich in protein) was much more thoroughly digested than the wide ration (relatively deficient in protein).

A large number of digestion experiments made in Germany indicate that the presence of large quantities of carbohydrates (starch) in a ration tends to lower the digestibility of the protein and fiber. This experiment points in the same direction. The wide ration had a large proportion of corn meal, which supplied large amounts of starch, while the narrow ration had but a small quantity of corn meal, but was relatively rich in protein. But whether these results are actual or only apparent, neither these experiments, nor those previously made, decide.

THE RATIONS EATEN.

Table 19, which follows, shows the total amount of hay and grain fed to each sheep for the whole period, the total nutrients and the digestible nutrients and also the averages for each day. The averages are given in heavy type so that the total ration for each sheep can be readily seen. Nos. 20-24 were fed a small quantity of turnips during the latter half of the experiments. These did not enter into the digestion experiments and their digestibility is estimated from the averages of other experiments. Only small quantities were eaten and hence their influence on the ration must have been slight.

The uneaten residues consisted of the coarse parts of the hay, together with some grain. The amounts uneaten were small and it was thought that no great error could be introduced by assuming their digestibility to be the same as that of the entire ration. Table 20 summarizes the total and digestible nutrients eaten by each sheep in the experiments. Wolff's (German) standard for fattening sheep per 75 pounds live weight is also given, and has a nutritive ratio of 1:5.5. The average of 11 experiments with 22 animals, conducted in five experiment stations of the United States is also given and has a nutritive ratio of 1:6.1. The fuel value of each of the rations of the experiment is less than that of the standards. In the experiment the sheep were fed on a basis of 75 pounds live weight. It will be noticed that the narrow ration contained a relatively large amount of protein and is narrower than either of the standards, and that the wide ration contains a relatively small amount of protein and is much wider than either of the standards.

TABLE 19.

Estimated Total and Digestible Nutrients in Food Eaten by Each Animal in Sheep Feeding Experiment, 1893-94.

LOT B.	Total of Feeds.	TOTAL NUTRIENTS.				DIGESTIBLE NUTRIENTS.		
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Protein.	Fat.	Carbohydrates.
WIDE RATION.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
<i>Sheep No. 20.</i>								
Corn meal, - - -	97.8 }	15.6	6.1	86.2	4.5	—	—	—
Wheat bran, - - -	32.6 }							
Hay, - - -	130.4 }							
Turnips, - - -	11.0 }							
Total furnished, -	271.8	30.2	10.8	140.0	45.1	16.7	7.4	131.5
Uneaten residue, -	4.4	.5	.1	2.6	.4	.3	.1	2.2
Total eaten in 133 days,	267.4	29.7	10.7	137.4	44.7	16.4	7.3	129.3
Average per day, - -	—	.223	.080	1.033	.336	.123	.055	.971
<i>Sheep No. 21.</i>								
Corn meal, - - -	105.3 }	16.7	6.6	92.8	4.8	—	—	—
Wheat bran, - - -	35.1 }							
Hay, - - -	140.5 }							
Turnips, - - -	11.0 }							
Total furnished, -	291.9	32.5	11.6	150.7	48.5	18.0	7.9	141.5
Uneaten residue, -	2.7	.3	.1	1.2	.8	.1	.1	1.4
Total eaten in 133 days,	289.2	32.2	11.5	149.5	47.7	17.9	7.8	140.1
Average per day, - -	—	.242	.086	1.124	.359	.135	.059	1.053
<i>Sheep No. 22.</i>								
Corn meal, - - -	99.4 }	15.8	6.2	87.6	4.6	—	—	—
Wheat bran, - - -	33.2 }							
Hay, - - -	132.5 }							
Turnips, - - -	11.0 }							
Total furnished, -	276.1	30.7	11.0	142.3	45.7	17.0	7.5	133.6
Uneaten residue, -	5.3	.6	.2	3.2	0.6	.4	.1	2.7
Total eaten in 133 days,	270.8	30.1	10.8	139.1	45.1	16.6	7.4	130.9
Average per day, - -	—	.226	.081	1.046	.339	.125	.056	.984
<i>Sheep No. 23.</i>								
Corn meal, - - -	91.7 }	14.6	5.8	80.8	4.2	—	—	—
Wheat bran, - - -	30.6 }							
Hay, - - -	122.3 }							
Turnips, - - -	11.0 }							
Total furnished, -	255.6	28.4	10.2	131.3	42.3	15.7	7.0	123.3
Uneaten residue, -	5.8	.7	.2	3.4	.8	.4	.2	3.0
Total eaten in 133 days,	249.8	27.7	10.0	127.9	41.5	15.3	6.8	120.3
Average per day, - -	—	.208	.075	.962	.312	.115	.051	.905

TABLE 19.—(Continued.)

Lot C.	Total of Feeds.	TOTAL NUTRIENTS.				DIGESTIBLE NUTRIENTS.		
		Protein.	Fat.	Nit.-free Ext	Fiber.	Protein.	Fat.	Carbohydrates.
NARROW RATION.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
<i>Sheep No. 26.</i>								
Lin. meal, 3 parts, } mix.,	34.1	32.5	5.4	68.4	9.9	—	—	—
Corn meal, 1 part, }	34.1							
Wheat bran, - - -	68.1							
Oat and pea meal, - - -	136.3	15.2	4.9	55.4	42.3	—	—	—
Hay, - - - - -								
Total furnished, - - -	272.6	47.7	10.3	123.8	52.2	35.0	7.3	125.2
Uneaten residue, - - -	2.9	.4	.1	1.4	.6	.3	.1	1.4
Total eaten in 133 days,	269.7	47.3	10.2	122.4	51.6	34.7	7.2	123.8
Average per day, - - -	—	.356	.077	.920	.388	.261	.054	.931
<i>Sheep No. 27.</i>								
Lin. meal, 3 parts, } mix.,	34.1	32.5	5.4	68.4	9.9	—	—	—
Corn meal, 1 part, }	34.1							
Wheat bran, - - -	68.1							
Oat and pea meal, - - -	136.3	15.2	4.9	55.4	42.3	—	—	—
Hay, - - - - -								
Total furnished, - - -	272.6	47.7	10.3	123.8	52.2	35.0	7.3	125.2
Uneaten residue, - - -	2.4	.4	.1	1.1	.6	.3	.1	1.2
Total eaten in 133 days,	270.2	47.3	10.2	122.7	51.6	34.7	7.2	124.0
Average per day, - - -	—	.356	.077	.923	.388	.261	.054	.932
<i>Sheep No. 28.</i>								
Lin. meal, 3 parts, } mix.,	33.3	31.7	5.2	66.7	9.7	—	—	—
Corn meal, 1 part, }	33.3							
Wheat bran, - - -	66.5							
Oat and pea meal, - - -	133.0	14.9	4.8	54.0	41.3	—	—	—
Hay, - - - - -								
Total furnished, - - -	266.1	46.6	10.0	120.7	51.0	34.2	7.1	122.2
Uneaten residue, - - -	2.4	.5	.1	1.1	.4	.3	—	1.1
Total eaten in 133 days,	263.7	46.1	9.9	119.6	50.6	33.9	7.1	121.1
Average per day, - - -	—	.347	.074	.899	.381	.255	.053	.910
<i>Sheep No. 29.</i>								
Lin. meal, 3 parts, } mix.,	34.7	33.0	5.5	69.7	10.1	—	—	—
Corn meal, 1 part, }	34.7							
Wheat bran, - - -	69.4							
Oat and pea meal, - - -	138.9	15.5	5.0	56.5	43.1	—	—	—
Hay, - - - - -								
Total furnished, - - -	277.7	48.5	10.5	126.2	53.2	35.6	7.4	127.6
Uneaten residue, - - -	1.3	.2	—	.6	.3	.2	—	.6
Total eaten in 133 days,	176.4	48.3	10.5	125.6	52.9	35.4	7.4	127.0
Average per day, - - -	—	.363	.079	.944	.398	.266	.056	.955

TABLE 19.—(Continued.)

GROUP D.	Total of Feeds.	TOTAL NUTRIENTS.				DIGESTIBLE NUTRIENTS.		
		Protein.	Fat.	Nit.-free Ext.	Fiber.	Protein.	Fat.	Carbo-hydrates.
<i>Six Sheep, Narrow Ration.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lin. meal, 3 parts, } Corn meal, 1 part, } mix.,	214.5	204.1	33.9	430.4	62.5	—	—	—
Wheat bran, - -	214.5							
Oat and pea meal, - -	420.0							
Hay, - - - -	858.0	95.9	30.8	348.8	266.3	—	—	—
Total furnished, -	1716.0	300.0	64.7	779.2	328.8	220.2	45.8	788.4
Uneaten residue, -	7.6	1.1	.2	3.2	2.0	.8	.1	3.7
Total eaten in 146 days,	1709.4	298.9	64.5	776.0	326.8	219.4	45.7	784.7
Av. per day per group,	—	2.047	.442	5.315	2.239	1.503	.313	5.375
Av. per day per head, -	—	.341	.074	.886	.373	.251	.052	.896

TABLE 20.

Average of Total and Digestible Nutrients Eaten Daily by Each Animal in Sheep Feeding Experiment of 1893-94.—Summary Standard Rations for 75 Pounds, Live Weight.

SHEEP NUMBER.	TOTAL NUTRIENTS EATEN.				DIGESTIBLE NUTRIENTS.*			
	Protein.	Fat.	Nit.-free Ext.	Fiber.	Protein.	Fat.	Carbo-hydrates.	Fuel Val.
<i>Wide Ration.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
No. 20, - -	.223	.080	1.033	.336	.123	.055	.971	2265
No. 21, - -	.242	.086	1.124	.359	.135	.059	1.053	2466
No. 22, - -	.226	.081	1.046	.339	.125	.056	.984	2300
No. 23, - -	.208	.075	.962	.312	.115	.051	.905	2205
Average, - -	.23	.08	1.04	.34	.13	.06	.98	2320
<i>Narrow Ration.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
No. 26, - -	.356	.077	9.20	.388	.261	.054	.931	2445
No. 27, - -	.356	.077	9.23	.388	.261	.054	.932	2445
No. 28, - -	.347	.074	8.99	.381	.255	.053	.910	2390
No. 29, - -	.363	.079	9.44	.398	.266	.056	.955	2505
Average, - -	.36	.08	.92	.39	.26	.05	.93	2425
<i>Group D.—Narrow Ration.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
Average per head,	.341	.074	.886	.373	.251	.052	.896	2355
<i>Standard Rations per 75 lbs. Live Weight.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.
German,† - -	—	—	—	—	.23	.04	1.14	2715
American, - -	—	—	—	—	.20	.07	1.08	2675

* The nutritive ratio of the wide ration is 1:8.7 and that of the narrow ration 1:4.1; that of the German standard is 1:5.5, and the American 1:6.2.

† See explanation, p. 97.

RESULTS OF THE EXPERIMENT.

At the end of the experiment, March 28, the animals were all sheared and the weights of the wool were taken. On March 29 the animals were all butchered and the internal organs and carcasses were weighed, and the meat sent to the laboratory for analysis.

The statistics at the time of butchering are given in Table 21.

TABLE 21.

Sheep Feeding Experiment, 1893-94.—Statistics of Animals.

SHEEP NO.	LIVE WEIGHT.*				WEIGHT OF ORGANS, ETC.					Wool.
	At Begin'g of Expt. Nov. 16.	At End of Expt. March 28.	Increase in 133 Days.	DRESSED WEIGHT.	Lungs and Windpipe.	Liver.	Heart and Aorta.	Kidneys.	Intestinal Fat.	
<i>Lot A.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
13, - - -	79.0	—	—	31.7	1.09	1.22	.38	.21	1.38	—
14, - - -	60.0	—	—	25.9	.94	.91	.25	.16	1.66	—
15, - - -	54.5	—	—	21.6	.69	1.03	.25	.13	1.00	—
16, - - -	54.5	—	—	23.1	.72	.81	.25	.16	1.16	—
17, - - -	56.0	—	—	22.9	.72	.60	.28	.14	1.56	—
Average, -	60.8	—	—	25.0	.83	.93	.28	.16	1.35	—
<i>Lot B.</i>										
Wide Ration.										
20, - - -	59.5	82.5	23.0	34.4	1.41	1.41	.41	.19	2.75	6.66
21, - - -	75.5	100.0	24.5	42.1	1.75	1.56	.41	.21	2.91	8.44
22, - - -	55.5	76.1	21.1	31.4	1.47	1.63	.38	.21	2.41	5.94
23, - - -	59.0	78.3	19.3	34.9	1.28	1.66	.41	.19	2.09	7.19
Average, -	62.4	84.4	22.0	35.7	1.48	1.57	.40	.20	2.54	7.06
<i>Lot C.</i>										
Narrow Ration.										
26, - - -	55.8	89.4	33.6	40.0	1.59	1.34	.50	.20	1.81	4.53
27, - - -	71.3	86.4	15.1	38.3	1.69	1.25	.34	.22	2.59	5.75
28, - - -	50.5	80.3	29.8	36.7	1.19	1.06	.44	.18	2.22	5.19
29, - - -	63.5	91.3	27.8	37.9	1.66	1.34	.38	.20	2.00	6.44
Average, -	60.3	86.9	26.6	38.2	1.53	1.25	.42	.20	2.16	5.48
<i>Group D. † 6 Sheep</i>										
Narrow Ration.										
Avg. per head, -	50.8	77.2	26.3	33.9	1.46	1.03	.37	—	2.04	4.61

* Including wool.

† Fed 146 days.

Lot A (Nos. 13-17) that had been killed November 16, was used as a basis for observing the effect of the ration on the composition of the meat. From the weights of the animals at the beginning and at the end of the experiment it will be seen that there was an increase in the live weight, including the growth of wool from 19.3 to 24.5 pounds in the case of the wide

ration lot (B), and from 15.1 to 33.6 pounds in the case of the narrow ration lot (C), while group D made an average gain of 26.6 pounds.

The average live weight of the animals of lot A (60.8 pounds), which were killed and analyzed at the beginning of the experiment, was practically the same as that of the two lots fed in single pens lots B and C (62.4 and 60.3 pounds). The average dressed weight of lot A was 25.0 pounds. The average dressed weight of the wide ration lot was 35.7, and of the narrow ration lot 38.2 pounds. If it is assumed that the animals of lots B and C would have dressed, at the start, the same as the average of lot A, the gain in dressed weight would have been 10.7 pounds for the wide ration lot and 13.2 pounds for the narrow ration lot.

There was practically no difference between the weights of the lungs, the hearts, and the kidneys of the narrow ration and the wide ration lots. The livers were one-third of a pound heavier in case of the wide ration sheep. In this respect the experiment differs from a similar one made the previous winter where the livers of the narrow ration lot were one-tenth of a pound heavier than in the wide ration lot.

The animals slaughtered at the beginning of the experiment had an average of 1.35 pounds of intestinal and caul fat. The narrow ration sheep gave an average increase of .8 pounds and the wide ration sheep 1.2 pounds of intestinal and caul fat.

The sheep were not sheared at the beginning of the experiment and hence it is not possible to get the increase of wool during the test. If we assume that the growth of wool was the same in the two lots at the start, the wide ration sheep must have made a much larger growth of wool, as the average weight of wool at the end of the experiment is 2.6 pounds greater for the wide ration sheep than it is for the narrow ration sheep. In the experiment of the previous winter where the sheep were sheared at the start, the narrow ration sheep grew heavier fleeces.

CHEMICAL COMPOSITION OF THE FLESH.

The flesh of the sheep of the narrow ration and the wide ration lots was analyzed. In each case the right side was used for analysis. The flesh of the entire side was carefully separated from the bones and then finely cut in a sausage machine. After thoroughly mixing the entire mass a small sample was taken and prepared for analysis. The results of the analyses calculated

both on water-free (dry matter) and fresh substance (flesh) are given in table 22, which follows.

TABLE 22.

Percentage Composition of Flesh (Edible Portion) of Animals in Sheep Feeding Experiment of 1893-94.

	CALCULATED ON WATER-FREE BASIS.			CALCULATED TO WATER CONTENT OF FLESH.			
	Protein.	Fat.	Ash.	Water.	Protein.	Fat.	Ash.
<i>At Beginning of Experiment.</i>	%	%	%	%	%	%	%
Sheep No. 13, - - -	41.93	55.89	2.18	58.19	17.53	23.37	.91
Sheep No. 14, - - -	33.56	64.63	1.81	52.41	15.97	30.76	.86
Sheep No. 15, - - -	39.24	58.68	2.08	57.24	16.78	25.09	.89
Sheep No. 16, - - -	33.87	64.26	1.87	53.47	15.76	29.90	.87
Sheep No. 17, - - -	34.38	63.71	1.91	54.53	15.63	28.97	.87
Average, - - -	36.60	61.43	1.97	55.17	16.33	27.62	.88
<i>Wide Ration.</i>							
Sheep No. 20, - - -	30.03	68.35	1.62	50.58	14.84	33.78	.80
Sheep No. 21, - - -	34.23	63.86	1.91	54.90	15.44	28.80	.86
Sheep No. 22, - - -	33.16	65.04	1.80	51.06	16.23	31.83	.88
Sheep No. 23, - - -	32.97	65.32	1.71	51.53	15.98	31.66	.83
Average, - - -	32.60	65.64	1.76	52.02	15.62	31.52	.84
<i>Narrow Ration.</i>							
Sheep No. 26, - - -	38.57	59.21	2.22	56.36	16.83	25.84	.97
Sheep No. 27, - - -	33.69	64.47	1.84	52.24	16.09	30.79	.88
Sheep No. 28, - - -	26.59	71.88	1.53	47.15	14.05	37.99	.81
Sheep No. 29, - - -	44.53	53.03	2.44	60.59	17.55	20.90	.96
Average, - - -	35.84	62.15	2.01	54.09	16.13	28.88	.91

In table 23, on the following page, are given the actual weights of nutrients, protein, fat, etc., in the total flesh of each animal of lots A, B and C. The pounds of nutrients, as shown in the last five columns at the right were obtained by multiplying the weight of flesh (edible portion) by the percentage composition of the flesh as given in table 22. The average percentage of fat in the dry matter was 2.6 higher in the case of the wide ration than with the narrow ration lot of sheep, while the average of protein was .5 per cent. higher in case of the narrow ration lot.

The ratio between the percentages of protein and fat in the dry matter at the beginning of the experiment was 1 to 1.7, and at the end was 1 to 1.8 for the narrow ration lot, and 1 to 2 for the wide ration lot. This shows that the sheep increased in relative fatness from the beginning of the experiment in each lot, and that the relative fatness was somewhat more in case of the wide ration lot.

TABLE 23.
Weights of Flesh and Nutrients in Flesh of Animals in Sheep Feeding Experiment, 1893-94.

	Live Weight.	Dressed Weight, without Kidneys and Hoofs.	Refuse (Bone).	Edible Portion (Flesh).	IN EDIBLE PORTION (FLESH).				
					Water.	Water-free Substance.	Water-free Sub.		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Protein.	Fat.	Ash.
<i>Beginning of Expt.</i>									
Sheep No. 13, -	79.0	30.76	6.86	23.90	13.90	10.00	4.19	5.59	.217
Sheep No. 14, -	60.0	24.94	4.44	20.50	10.74	9.76	3.27	6.30	.176
Sheep No. 15, -	54.5	20.58	4.60	15.98	9.15	6.83	2.68	4.01	.142
Sheep No. 16, -	54.5	22.26	5.06	17.20	9.20	8.00	2.71	5.14	.150
Sheep No. 17, -	56.0	21.28	4.52	16.76	9.14	7.62	2.62	4.86	.146
Average, -	60.8	23.97	5.10	18.87	10.43	8.44	3.09	5.18	.166
<i>Wide Ration.</i>									
Sheep No. 20, -	82.5	33.56	5.96	27.60	13.96	13.64	4.10	9.32	.221
Sheep No. 21, -	100.0	40.00	7.26	32.74	17.96	14.78	4.06	9.43	.282
Sheep No. 22, -	76.1	29.72	6.04	23.68	14.35	9.33	3.84	7.54	.208
Sheep No. 23, -	78.3	32.68	5.18	27.50	14.17	13.33	4.39	8.71	.228
Average, -	84.4	33.99	6.11	27.88	15.11	12.77	4.09	8.75	.245
<i>Narrow Ration.</i>									
Sheep No. 26, -	89.4	37.66	6.38	31.28	17.63	13.65	5.26	8.08	.303
Sheep No. 27, -	86.4	36.88	6.44	30.44	15.90	14.54	4.90	9.37	.268
Sheep No. 28, -	80.3	34.10	4.44	29.66	13.98	15.68	4.16	11.27	.240
Sheep No. 29, -	91.3	35.26	6.28	28.98	17.56	11.42	5.09	6.06	.277
Average, -	86.9	35.98	5.89	30.09	16.27	13.82	4.85	8.69	.272

The average differences in composition are pointed out in the following table:

Differences in Weights of Nutrients with Different Rations.

LOT B (NARROW). LOT C (WIDE).	Edible Portion (Flesh).	IN EDIBLE PORTION (FLESH).				
		Water.	Water-free Substance.	In Water-free Substance.		
				Protein.	Fat.	Ash.
<i>Increase over Beginning of Experiment.</i>	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wide ration group, average of 4 animals,	9.01	4.68	4.33	1.00	3.57	.08
Narrow ration group, average of 4 animals, - - - - -	11.22	5.84	5.38	1.76	3.51	.10
Increase of narrow ration over wide ration group, - - - - -	2.21	1.16	1.05	.76	-.06	.02

The increase in dry matter, water and protein was to have been expected from the percentage composition.

SUMMARY.

The experiment was undertaken in order to observe the effects of different kinds of food upon the chemical composition of the flesh of sheep. The plan consisted each year in selecting a number of sheep of the same breed and age, and as nearly alike as possible, and dividing them into three groups. One group was butchered at the beginning of the experiment and the flesh analyzed. The results of the weighings and analyses of this group served to indicate more or less accurately the condition of the other animals at the beginning of the experiment. The two other groups were fed differently, one upon a wide ration relatively deficient in protein, the other upon a narrow ration relatively rich in protein. At the end of the experiment the animals were all butchered and the flesh analyzed. The experiment has been continued through two years, with no very decisive results. That food determines to a great extent the character and chemical composition of the flesh is made clear, but the animals made so little growth that it is unwise to draw definite conclusions of a practical nature from the results of the experiments.

The tables which follow give the condensed statistics of the experiments for two years.

Summary of Daily Rations Fed, and Averages of Digestible Nutrients Eaten, and Gain in Live and Dressed Weights of Animals.

	DIGESTIBLE NUTRIENTS IN FOOD ACTUALLY EATEN.				INCREASE.		
	Total Organic Matter.	Protein.	Fat.	Carbohy- drates.	Fuel Value.	Live wgt., in- clud'g fleece.	Dressed Wgt.
	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.	Lbs.
Wide ration, 1893, - - -	1.92	.23	.09	1.60	3785	.27	.16
Wide ration, 1894, - - -	1.17	.13	.06	.98	2320	.16	.08
Narrow ration, 1893, - - -	1.90	.39	.06	1.45	3675	.32	.19
Narrow ration, 1894, - - -	1.24	.26	.05	.93	2425	.20	.10
<i>To produce a gain of 1 lb., Live Wgt.</i>							
Wide ration, 1893, - - -	6.99	.82	.33	5.84	14000	1.00	.6
Wide ration, 1894, - - -	7.31	.81	.38	6.13	14500	1.00	.5
Narrow ration, 1893, - - -	6.02	1.23	.19	4.60	11500	1.00	.6
Narrow ration, 1894, - - -	6.20	1.30	.25	4.65	12100	1.00	.5
<i>To produce a gain of 1 lb., Drs'd Wgt.</i>							
Wide ration, 1893, - - -	11.74	1.38	.55	9.81	23600	1.7	1.0
Wide ration, 1894, - - -	14.62	1.62	.76	12.26	29000	2.0	1.0
Narrow ration, 1893, - - -	10.23	2.10	.32	7.81	19300	1.7	1.0
Narrow ration, 1894, - - -	12.40	2.60	.50	9.30	24300	2.0	1.0

Percentage Composition of Flesh, Edible Portion of Animals in Sheep Feeding Experiments of 1893 and 1894.

	CALCULATED ON WATER-FREE BASIS.			CALCULATED TO WATER CONTENT OF FLESH.			
	Protein.	Fat.	Ash.	Water.	Protein.	Fat.	Ash.
<i>Beginning of Experiment.</i>	%	%	%	%	%	%	%
1893, - - - -	41.4	56.1	2.5	58.4	17.2	23.4	1.0
1894, - - - -	36.6	61.4	2.0	55.2	16.3	27.6	.9
<i>Wide Ration.</i>							
1893, - - - -	34.9	63.2	1.9	57.3	14.9	27.0	.8
1894, - - - -	32.6	65.6	1.8	52.0	15.6	31.5	.9
<i>Narrow Ration.</i>							
1893, - - - -	36.5	61.5	2.0	58.8	15.0	25.4	.8
1894, - - - -	35.8	62.2	2.0	54.1	16.1	28.9	.9

Differences in Weights of Nutrients with Different Rations.

	Edible Portion (Flesh).	IN EDIBLE PORTION (FLESH).				
		Water.	Water-free Substance.	In Water-free Substance.		
				Protein.	Fat.	Ash.
Wide ration group, Aug. 5, animals,	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1893, - - - -	12.12	6.72	5.44	1.24	4.15	.05
Wide ration group, Aug. 5, animals,						
1894, - - - -	9.01	4.68	4.33	1.00	3.57	.08
Narrow ration group, Aug. 4, ani-						
mals, 1893, - - - -	14.38	8.57	5.81	1.64	4.11	.06
Narrow ration group, Aug. 4, ani-						
mals, 1894, - - - -	11.22	5.84	5.38	1.76	3.51	.10
Increase of narrow ration over wide						
ration group, 1893, - - - -	2.22	1.85	.37	.40	-.04	.01
Increase of narrow ration over wide						
ration group, 1894, - - - -	2.21	1.16	1.05	.76	-.06	.02

DIGESTION EXPERIMENTS WITH SHEEP.

* BY C. S. PHELPS AND CHAS. D. WOODS.

It is a matter of every-day experience that only a part of the food eaten is actually used by the animal. It is, therefore, of importance in cattle feeding to have a knowledge, not only of the chemical composition of a given food, but of the amounts of the nutrients which are capable of being assimilated. It is not so much what an animal eats, as that which it digests,* that is actually turned to account.

Many analyses have been made of the different materials commonly used for food for cattle, and we have a fairly good knowledge of their composition. A good many experiments upon the digestibility of the different feeding stuffs have been made, but these are necessarily much less in number, and also less accurate than the analyses. Considering the short time that the experiment stations have been in operation in this country, the number of digestion experiments upon American feeding stuffs is quite considerable, but by far the larger number of experiments of this kind have been made in Europe and especially in Germany. Just as it had been of great practical importance to make large numbers of analyses in order that we may know the average composition of American feeding stuffs, so it is important to have a large number of accurately conducted digestion experiments upon American feeding materials. The results already obtained are in many instances more valuable for our conditions than are those of the much larger number of German experiments.

Partly to add to the stock of knowledge upon this important subject and partly because of the need of the results for use in connection with its feeding experiments, the Station began a year ago a series of digestion experiments with sheep.

* The word digestibility as commonly used has more than one meaning. People often speak of one food as being more digestible than another, when they mean it is more quickly or easily digested. As here used, the term digestibility means the proportion of any given food or food constituent which is digested under usual conditions, without regard to the length of time or the ease of digestion.

DIGESTION EXPERIMENTS—HOW CONDUCTED.

A digestion experiment is usually managed as follows: Selected animals are fed with the kind or kinds of feeding stuffs to be tested. The feeding stuffs are carefully analyzed. A weighed portion is fed, care being taken to see that none is wasted, and that all the uneaten residues are weighed and analyzed. In this way the exact weights of protein, fat, fiber, nitrogen-free extract and ash eaten are ascertained.* The solid excrement of the animal contains the undigested residues. This is carefully collected, dried, weighed and analyzed, and the amounts of undigested protein, fat, fiber, nitrogen-free extract and ash contained in it are found. The difference between the amounts found in the undigested residues and the amounts contained in the food eaten is taken as a measure of the amounts of the various nutrients which have been digested and assimilated by the animals.

While such an experiment seems comparatively simple, it is surrounded by a number of difficulties which make the work laborious and tend to make the results somewhat uncertain.

INFLUENCE OF THE ANIMAL UPON DIGESTIBILITY.

The results of digestion experiments in Germany warrant the following general conclusions upon the influence of species, breed, etc., upon digestibility of feeding stuffs.

Influence of Kind of Animals.—All ruminants, such as cows, oxen, sheep and goats, seem to digest practically the same amount of protein, fat, nitrogen-free extract and fiber from the same kind of food. In general, horses digest less of the food constituents than do ruminants. This is especially true of the fiber and fat in the hays and grasses.

Influence of Breed.—The influence of breed upon digestibility has been studied with sheep, but no differences due to breed have been found. In general, it is probably true that different breeds of animals of the same species digest practically the same amounts of nutrients of the same food.

Influence of the Individual.—Individual differences have always been observed. The variation is quite wide, and on this account the results with the influences of kinds and breed of animals are somewhat obscured, variations in amounts digested by different

* For explanation of constituents and uses of feeding stuffs, see pp. 43 and 44 of this Report.

individual animals of the same species and breed being wider than most variations in different species.

Influence of Age.—The few experiments (principally with sheep) tried indicate very little difference, if any, due to age.

EXPERIMENTS HERE REPORTED.

From the above it will be seen that differences due to age, breed and species of ruminants are slight. The digestibility of a feed by a sheep can be taken as a tolerably correct measure of its digestibility by a cow or steer. As sheep are easier to experiment with than are larger animals, and as many of the feeding experiments by the Station are with sheep, they have been employed in the digestion experiments which are here reported upon.

The pens for the animals are similar to those devised by the Maine Experiment Station* except that the partitions and sides were made of half-inch iron pipe. The pen for each animal is about five feet square and has at one side a narrow stall in which the sheep is confined during the part of the experiment in which the feces are collected. The mangers are arranged so as to prevent loss of food by scattering. The rubber-lined bags for collecting the feces and the harness used to hold them in place are quite similar to those used by the Maine Station.

Each experiment lasted twelve days. The first seven days were given to preliminary feeding, during which the feces were not collected and each animal had the run of its pen. At the end of the first seven days the sheep were placed in the narrow stall and the rubber-lined bags for collecting the feces were attached. The whole of the feces was collected during the last five days of the experiment, and was removed twice daily from the bags and placed in the drying apparatus. Each half day's portion of the feces was dried by itself, put in a glass jar and sent to the laboratory for analyses.

The details of the experiments follow.

DIGESTION EXPERIMENT NO. I.

Wheat bran, corn meal and hay.

Two grade Shropshire wethers of preceding spring. Experiment began January 11, 1894, and ended January 23, 1894. Feces collected for five days from January 18 at 1:30 P. M. to January 23 at 1:30 P. M.

* Report Maine Agricultural Experiment Station, 1891, pp. 25-28.

The amounts fed daily were as follows: Wheat bran, 4 ounces; corn meal, 12 ounces; hay, 1 pound, being the wide ration used in the sheep feeding experiments described on page 94 of this Report. With sheep D the experiment was apparently normal throughout. Sheep B had a slight tendency to diarrhœa toward the end of the experiment. This may account for the larger weight of feces in the case of B and the consequent lower coefficients of digestion.

Tables 23 and 24, which follow, give the details of the experiment.

TABLE 23.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N×6.25	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuffs.</i>								
Bran,* - - -	1301	% 9.2	% 17.1	% 5.4	% 52.7	% 10.2	% 5.4	% 85.4
Corn meal,* - - -	1300	12.4	10.2	4.3	70.6	1.3	1.2	86.4
Hay,* - - -	1325	8.8	10.9	3.7	40.3	31.1	5.2	86.0
<i>Feces.</i>								
Sheep B, - - -	1307	8.7	15.2	4.2	38.8	24.1	9.0	82.3
Sheep D, - - -	1308	8.5	14.2	3.7	41.7	22.9	9.0	82.5

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 24.
Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N×6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>							
Bran, - - -	*Grams. 567	Grams. 97	Grams. 31	Grams. 299	Grams. 58	Grams. 31	Grams. 485
Corn meal, - - -	1701	173	73	1201	22	20	1469
Hay, - - -	2268	247	84	914	705	118	1950
Total, - - -	4536	517	188	2414	785	169	3904
<i>Feces 5 Days.</i>							
Sheep B, - - -	1770	269	74	687	427	159	1457
Sheep D, - - -	1382	196	51	576	317	124	1140
<i>Amounts Digested.</i>							
Sheep B, - - -	2766	248	114	1727	358	10	2447
Sheep D, - - -	3154	321	137	1838	408	45	2764
<i>Per Cent. Digested.</i>							
Sheep B, - - -	—	% 48.0	% 60.6	% 71.5	% 45.6	% 5.9	% 62.7
Sheep D, - - -	—	62.1	72.9	76.1	59.6	26.6	70.8
Average, - - -	—	55.1	66.8	73.8	52.6	16.3	66.8

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 2.

Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.

Animals: as in Experiment No. 1. Experiment began February 5, 1894, and ended February 17, 1894. Feces collected for five days from February 12 at 3 P. M. to February 17 at 3 P. M. The amounts fed daily were as follows: Wheat bran, 4 ounces; corn meal, 1 ounce; linseed meal, 3 ounces; oat and pea meal, 8 ounces; hay, 1 pound. The experiment with both animals was apparently normal throughout. Tables 25 and 26, which follow, give the details of the experiment.

TABLE 25.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuffs.</i>								
Linseed mixture,*	1302	10.5	30.1	5.5	43.6	6.0	4.3	85.2
Wheat bran,*	1304	8.8	18.1	5.1	52.0	10.2	5.8	85.4
Oats and peas,*	1303	11.5	23.9	2.5	52.1	6.6	3.4	85.1
Hay,*	1326	8.2	11.4	3.6	41.7	30.1	5.0	86.8
<i>Feces.</i>								
Sheep B,	1309	7.6	14.9	4.2	38.2	24.4	10.7	81.7
Sheep D,	1310	7.4	16.7	3.5	37.6	24.0	10.8	81.8

* For analysis calculated to water-free substance, see pp. 23-25 of this Report.

TABLE 26.

Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.-free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>							
Linseed mixture, -	*Grams. 567	Grams. 171	Grams. 31	Grams. 247	Grams. 34	Grams. 24	Grams. 483
Wheat bran, -	567	103	29	295	57	33	484
Oats and peas, -	1134	271	28	591	75	39	965
Hay, -	2268	258	82	946	683	113	1969
Total, -	4536	803	170	2079	849	209	3901
<i>Feces 5 Days.</i>							
Sheep B, -	1427	213	60	545	348	153	1166
Sheep D, -	1386	231	49	521	333	150	1134
<i>Amounts Digested.</i>							
Sheep B, -	3109	590	110	1534	501	56	2735
Sheep D, -	3150	572	121	1558	516	59	2767
<i>Per Cent. Digested.</i>							
Sheep B, -	—	73.5	64.7	73.8	59.0	26.8	70.1
Sheep D, -	—	71.2	71.2	74.9	60.8	28.2	70.9
Average, -	—	72.3	67.9	74.3	59.9	27.5	70.5

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 3.

Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.

The experiment was a duplicate of No. 2 with the animals and feed. The experiment began February 17, 1894, and ended March 1, 1894. Feces collected for five days from February 24 at 2:30 P. M. to March 1 at 2:30 P. M. The experiment was apparently normal throughout with both animals except that toward the close the feces of sheep B became quite soft, which may account for the larger weight of feces in the case of D and the consequent lower coefficient of digestion. Tables 27 and 28, which follow, give the details of the experiment.

TABLE 27.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuffs.</i>		%	%	%	%	%	%	%
Linseed mixture,* -	1339	11.1	29.4	5.5	43.7	6.1	4.2	84.7
Wheat bran,* -	1338	8.7	16.6	5.1	53.2	10.3	6.1	85.2
Oats and peas,* -	1340	11.4	22.2	2.5	52.9	7.7	3.3	85.3
Hay,* - - -	1327	8.5	11.1	3.6	39.2	32.3	5.3	86.2
<i>Feces.</i>								
Sheep B, - - -	1311	4.4	15.2	4.0	40.8	24.5	11.1	84.5
Sheep D, - - -	1312	5.5	15.5	3.2	38.4	25.3	12.1	82.4

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 28.
Weights of Food Eaten and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>	*Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Linseed mixture, - - -	567	167	31	248	34	24	480
Wheat bran, - - -	567	94	29	302	58	34	483
Oats and peas, - - -	1134	252	28	600	87	37	967
Hay, - - - - -	2268	252	81	889	733	120	1955
Total, - - - - -	4536	765	169	2039	912	215	3885
<i>Feces 5 Days.</i>							
Sheep B, - - - - -	1149	175	46	460	281	127	971
Sheep D, - - - - -	1402	217	45	538	355	170	1155
<i>Amounts Digested.</i>							
Sheep B, - - - - -	3387	590	123	1570	631	88	2914
Sheep D, - - - - -	3134	548	124	1501	557	45	2730
<i>Per Cent. Digested.</i>		%	%	%	%	%	%
Sheep B, - - - - -	—	77.1	72.8	77.0	69.2	40.9	75.0
Sheep D, - - - - -	—	71.6	73.4	73.6	61.1	20.9	70.3
Average, - - - - -	—	74.4	73.1	75.3	65.1	30.9	72.7

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 4.

Wheat bran, corn meal and hay.

This experiment is a duplicate of No. 1 with the same animals and feed. The experiment began March 3 and ended March 15, 1894. Feces collected for five days from March 10 at 9 A. M. to March 15 at 9 A. M. The experiment was apparently normal with both animals.

Tables 29 and 30, which follow, give the details of the experiment.

TABLE 29.

Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuffs.</i>								
Corn meal, - -	1305	12.4	10.0	4.8	70.3	1.3	1.2	86.4
Wheat bran, - -	1306	8.7	16.8	5.2	54.1	9.4	5.8	85.5
Hay, - - -	1328	7.8	11.2	3.5	41.4	30.7	5.4	86.8
<i>Feces.</i>								
Sheep B, - -	1313	8.1	17.0	4.6	37.6	23.5	9.2	82.7
Sheep D, - -	1314	8.4	17.2	3.8	37.8	24.0	8.8	82.8

TABLE 30.

Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>							
	Grams*	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Corn meal, - - -	1700	170	82	1195	22	20	1469
Wheat bran, - - -	568	95	30	307	53	33	485
Hay, - - -	2268	254	79	939	696	122	1968
Total, - - -	4536	519	191	2441	771	175	3922
<i>Feces for 5 Days.</i>							
Sheep B, - - -	1292	220	59	486	303	119	1068
Sheep D, - - -	1441	248	55	544	346	127	1193
<i>Amounts Digested.</i>							
Sheep B, - - -	3244	299	132	1955	468	56	2854
Sheep D, - - -	3095	271	136	1897	425	48	2729
<i>Per Cent. Digested.</i>							
Sheep B, - - -	—	57.6	69.1	80.1	60.7	32.0	72.8
Sheep D, - - -	—	52.2	71.2	77.7	55.2	27.4	69.6
Average, - - -	—	54.9	70.2	78.9	58.0	29.7	71.2

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 5.

Scarlet clover fodder.

Three animals, wethers, about one year old. Sheep, A, B and C were grade Shropshire dropped in the spring of 1893, and sheep B was grade Merino, also dropped in the spring of 1893. The experiment began May 26, 1894, and ended June 8, 1894. Feces collected for five days from June 3 at 8 A. M. to June 8 at 8 A. M. A and B were each fed ten pounds daily of the green scarlet clover and sheep D was fed eight pounds daily. The clover was cut at three different times, namely, May 26, May 28 and June 2. Each lot was sampled and analyzed by itself. At the time of taking the first sample, No. 1341, the clover was not quite in full bloom. Later, May 28, when sample 1342 was taken, the clover was in full bloom, and June 2, when the third sample was taken, the clover was a little past full bloom, the lower half of heads beginning to form the seed. The average of the last two cuttings, samples 1342 and 1343, were assumed to represent the average composition of the feed when used. The experiment with all three of the sheep was apparently normal throughout.

Tables 31 and 32, which follow, give the details of the experiment.

TABLE 31.

Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuff.</i>		%	%	%	%	%	%	%
<i>Scarlet Clover,* Fed Green.</i>								
Sample 1, - -	1341	87.3	2.5	.6	5.0	3.3	1.3	11.4
Sample 2, - -	1342	83.9	2.7	.6	7.0	4.4	1.4	14.7
Sample 3, - -	1343	84.4	2.9	.7	6.2	4.2	1.6	14.0
Avg. of 1342 & 1343,	—	—	2.8	.7	6.6	4.3	1.5	14.4
<i>Feces.</i>								
Sheep A, - -	1344	7.1	11.6	4.1	30.0	35.2	12.0	80.9
Sheep B, - -	1345	7.4	11.6	4.8	30.6	33.4	12.2	80.4
Sheep D, - -	1346	9.0	11.4	3.9	30.6	33.7	11.4	79.6

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 32.

Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
	Grams *	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
<i>Eaten in 5 Days.</i>							
Sheep A, - - -	22680	635	159	1497	975	340	3266
Sheep B, - - -	22680	635	159	1497	975	340	3266
Sheep D, - - -	18140	508	127	1197	780	272	2612
<i>Feces for 5 Days.</i>							
Sheep A, - - -	1273	148	52	382	448	153	1030
Sheep B, - - -	1229	143	59	376	410	150	988
Sheep D, - - -	1014	116	39	310	342	116	807
<i>Amounts Digested.</i>							
Sheep A, - - -	21407	487	107	1115	527	187	2236
Sheep B, - - -	21451	492	100	1121	565	190	2278
Sheep D, - - -	17126	392	88	887	438	156	1805
<i>Per Cent. Digested.</i>							
Sheep A, - - -	—	%	%	%	%	%	%
Sheep A, - - -	—	76.7	67.3	74.5	54.1	55.0	68.5
Sheep B, - - -	—	77.5	62.9	74.9	57.9	55.9	69.8
Sheep D, - - -	—	77.2	69.3	74.1	56.2	57.4	69.1
Average, - - -	—	77.1	66.5	74.5	56.1	56.1	69.1

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 6.

Barley fodder.

Two animals, A and D of experiment No. 5. Experiment began October 6, 1894, and ended October 18, 1894. Feces collected for five days from October 13 at noon to October 18 at noon. Each sheep was fed six pounds per day of the barley fodder. The barley was cut for feeding and samples were taken at four different times, namely, October 8, 11, 13, 15. At the time of taking the first sample, No. 1370, the barley was nearly grown and in full bloom. When the second sample was taken the barley was in bloom and beginning to seed. When the third sample, No. 1374, was taken, the barley was in early seeding and at the time of the last cutting it was still succulent. It was thought that it would be more nearly correct to use the average of the analyses of the second and third cuttings for the purpose of the experiment. With both animals the experiment was apparently normal throughout, except sheep A did not eat quite all the fodder which was fed.

Tables 33 and 34, which follow, give the details of the experiment.

TABLE 33.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuff.</i>		%	%	%	%	%	%	%
<i>Barley Fodder,* Fed Green.</i>								
Sample 1, - -	1370	78.1	3.5	.9	9.8	5.8	1.9	20.0
Sample 2, - -	1372	76.7	3.6	.9	9.1	7.5	2.2	21.1
Sample 3, - -	1374	76.6	3.7	.9	10.3	6.4	2.1	21.3
Sample 4, - -	1376	75.3	3.5	.9	12.0	6.5	1.8	22.9
Avg. of 1372 & 1374.	—	—	3.6	.9	9.7	7.0	2.2	21.2
<i>Feces.</i>								
Sheep A, - -	1383	6.8	11.2	3.5	30.4	36.7	11.4	81.8
Sheep B, - -	1384	6.2	13.7	4.4	30.6	34.0	11.1	82.7
<i>Uneaten Residue.</i>								
Sheep A, - -	1409	8.2	16.5	4.3	39.4	23.8	7.8	84.0

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 34.
Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>	Grams*	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep B, - - -	13610	490	122	1320	953	299	2885
Sheep A, fed, - - -	13463	466	116	1262	918	288	2762
<i>Uneaten Residue.</i>							
Sheep A, - - -	147	24	6	58	35	11	123
<i>Feces for 5 Days.</i>							
Sheep A, - - -	1275	143	45	387	468	145	1043
Sheep B, - - -	1022	140	45	313	347	113	845
<i>Amounts Digested.</i>							
Sheep A, - - -	12188	323	71	875	450	143	1719
Sheep B, - - -	12588	350	77	1007	606	186	2040
<i>Per Cent. Digested.</i>		%	%	%	%	%	%
Sheep A, - - -	—	69.3	61.2	69.3	49.0	49.7	62.2
Sheep B, - - -	—	71.4	63.1	76.3	63.6	62.2	70.7
Average, - - -	—	70.4	62.2	72.8	56.3	55.9	56.5

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 7.

Barley and pea fodder.

Tables 35 and 36, which follow, give the details of the experiment. The description of the experiment follows the tables.

TABLE 35.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuffs.</i>		%	%	%	%	%	%	%
<i>Barley & Pea Fodder,*</i>								
<i>Fed Green.</i>								
Sample 1, - -	1369	81.8	3.8	.8	7.3	4.7	1.6	16.6
Sample 2, - -	1371	80.6	3.7	.8	8.0	5.1	1.8	17.6
Sample 3, - -	1373	79.6	4.2	1.0	8.6	4.9	1.6	18.7
Sample 4, - -	1375	79.9	3.9	.7	8.7	5.2	1.6	18.5
Average of 1371 and 1373, - - -	—	—	4.0	.9	8.3	5.0	1.7	18.2
<i>Feces.</i>								
Sheep C, - -	1385	6.1	10.1	4.2	36.5	33.7	9.4	84.5
Sheep D, - -	1386	6.5	11.6	4.5	37.1	29.2	11.1	82.4
<i>Uneaten Residue.</i>								
Sheep D, - -	1417	6.5	11.9	2.2	38.4	32.1	8.9	84.6

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 36.
Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>	Grams*	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C, - - -	13610	544	122	1130	681	231	2477
Sheep D, fed, - -	13136	488	112	948	529	189	2077
<i>Uneaten Residue.</i>							
Sheep D, - - -	474	56	10	182	152	42	400
<i>Feces for 5 Days.</i>							
Sheep C, - - -	1022	103	43	373	345	96	864
Sheep D, - - -	1130	131	51	419	330	125	931
<i>Amounts Digested.</i>							
Sheep C, - - -	12588	441	79	757	336	135	1613
Sheep D, - - -	12006	357	61	529	199	64	1146
<i>Per Cent. Digested.</i>		%	%	%	%	%	%
Sheep C, - - -	—	81.1	64.8	67.0	49.3	58.4	65.1
Sheep D, - - -	—	73.2	54.5	55.8	37.6	33.9	55.2
Average, - - -	—	77.2	59.7	61.4	43.5	46.2	60.2

* One pound contains 454 grams.

Two animals, B and C, of digestion experiment No. 5. Experiment began October 6, 1894, and ended October 18, 1894. Feces collected for five days from October 13, noon, to October 18, noon. Each sheep was fed daily six pounds of the green fodder. The fodder was cut at four different times, October 8,

11, 13 and 15. At the time of the first cutting, sample 1369, the barley was nearly grown and in early bloom; the peas were beginning to bloom. At the time of the second cutting, sample 1371, the barley was nearly grown, in bloom and beginning to seed. The peas had blossoms. At the time of the third cutting, sample 1373, the barley was in early seeding and the peas in full bloom; and at the time of the last cutting, sample 1375, the barley was in early seeding and still succulent, peas mostly still green and in bloom. The average of the analyses of the second and third cuttings were assumed to represent the composition of the food experimented upon. With both animals the experiment was apparently normal throughout, except that sheep D did not eat up all of the fodder which was given it.

DIGESTION EXPERIMENT NO. 8.

Rowen hay from mixed grasses.

Four animals, wethers, the same as used in experiments 5, 6, and 7. Experiment began November 16 and ended November 28, 1894. Feces of C and D were collected for four and one-half days, from November 24 at 6 A. M. to November 28 at 4:30 P. M. The feces of sheep C and D were collected for five days, from November 23 at 4:30 P. M. to November 28 at 4:30 P. M. Each animal was fed two pounds of the rowen daily. The rowen was from mixed grasses, chiefly Kentucky blue grass and a little orchard grass and meadow fescue. It was grown by the Station in 1894 and harvested about September 25. With all four sheep the experiment was apparently normal throughout.

Tables 37 and 38, which follow, give the details of the experiment.

TABLE 37.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuff.</i>		%	%	%	%	%	%	%
Rowen hay,* from mixed grasses, -	1400	14.8	14.6	4.5	35.6	24.1	6.4	78.8
<i>Feces.</i>								
Sheep A, - -	1395	5.6	14.1	7.2	37.2	26.4	9.4	84.9
Sheep B, - -	1396	6.2	13.9	7.4	38.6	24.4	9.5	84.3
Sheep C, - -	1397	5.9	13.1	7.4	40.3	24.7	8.6	85.5
Sheep D, - -	1398	5.9	14.7	7.9	37.4	24.4	9.7	84.4

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 38.

Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times 6.25$.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 4½ Days.</i>	Grams *	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	4080	596	184	1452	983	261	3215
Sheep B, - - -	4080	596	184	1452	983	261	3215
<i>Eaten in 5 Days.</i>							
Sheep C, - - -	4535	661	204	1613	1092	290	3570
Sheep D, - - -	4535	661	204	1613	1092	290	3570
<i>Feces for 4½ Days.</i>							
Sheep A, - - -	1260	178	91	469	332	118	1070
Sheep B, - - -	1393	193	103	538	340	132	1174
<i>Feces for 5 Days.</i>							
Sheep C, - - -	1500	197	111	604	370	129	1282
Sheep D, - - -	1424	209	113	533	347	138	1202
<i>Amounts Digested.</i>							
Sheep A, - - -	2820	418	93	983	651	143	2145
Sheep B, - - -	2687	403	81	914	643	129	2041
Sheep C, - - -	3035	464	93	1009	722	161	2288
Sheep D, - - -	3111	452	91	1080	745	152	2368
<i>Per Cent. Digested.</i>		%	%	%	%	%	%
Sheep A, - - -	—	70.1	50.5	67.7	66.2	54.8	66.7
Sheep B, - - -	—	67.6	44.0	62.9	65.4	49.4	63.5
Sheep C, - - -	—	70.2	45.6	62.6	66.1	55.5	64.1
Sheep D, - - -	—	68.4	44.6	67.0	68.2	52.4	66.3
Average, - - -	—	69.1	46.2	65.1	66.5	53.0	65.2

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 9.

Rowen hay, mostly timothy.

The same animals were used as in experiments 5 to 8. The experiment was begun December 3, 1894, and ended December 15, 1894. Feces were collected for five days, from December 10 at 5 P. M. to December 15 at 5 P. M. Each sheep received daily two pounds of the rowen. The rowen consisted chiefly of timothy with a little barn grass. With all four sheep the experiment was apparently normal throughout, except that sheep D left some uneaten portions of that which was fed to it. Tables 39 and 40, which follow, give the details of the experiment.

TABLE 39.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuff.</i>		%	%	%	%	%	%	%
Rowen hay,* mostly timothy, - -	1399	18.6	13.2	4.3	32.5	24.8	6.6	74.8
<i>Feces.</i>								
Sheep A, - -	1401	8.0	13.8	6.5	35.1	26.6	10.0	82.0
Sheep B, - -	1402	7.0	12.5	6.9	39.3	29.1	5.2	87.8
Sheep C, - -	1403	7.8	12.9	6.8	36.5	26.5	9.5	82.7
Sheep D, - -	1404	8.0	14.1	7.3	37.2	21.9	11.5	80.5
<i>Uneaten Residue.</i>								
Sheep D, - -	1410	6.4	10.4	2.6	48.0	25.0	7.6	86.0

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 40.
Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>	Grams*	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	4535	598	195	1474	1125	299	3392
Sheep B, - - -	4535	598	195	1474	1125	299	3392
Sheep C, - - -	4535	598	195	1474	1125	299	3392
Sheep D, fed, - -	4216	565	187	1321	1045	275	3118
<i>Uneaten Residue.</i>							
Sheep D, - - -	319	33	8	153	80	24	274
<i>Feces for 5 Days.</i>							
Sheep A, - - -	1473	203	96	517	392	147	1208
Sheep B, - - -	1467	183	101	577	427	76	1288
Sheep C, - - -	1474	190	100	538	391	140	1219
Sheep D, - - -	1270	179	93	472	278	146	1022
<i>Amounts Digested.</i>							
Sheep A, - - -	3062	395	99	957	733	152	2184
Sheep B, - - -	3068	415	94	897	698	223	2104
Sheep C, - - -	3061	408	95	936	734	159	2173
Sheep D, - - -	2946	386	94	849	767	129	2096
<i>Per Cent. Digested.</i>		%	%	%	%	%	%
Sheep A, - - -	—	66.1	50.8	64.9	65.2	50.8	64.4
Sheep B, - - -	—	69.4	48.2	60.9	62.0	74.6	62.0
Sheep C, - - -	—	68.2	48.7	63.5	65.2	53.2	64.1
Sheep D, - - -	—	68.3	50.3	64.3	73.4	46.9	67.2
Average, - - -	—	68.0	49.5	63.4	68.5	56.4	64.4

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 10.

Scarlet clover hay, field cured.

The animals were the same as in experiments 5 to 9. The experiment began December 26, 1894, and ended January 7, 1895.

Feces were collected for five days from January 2, 5 P. M., to January 7, 5 P. M. Each sheep was fed daily one and one-half pounds of the rowen. The scarlet clover hay was cut June 4, 1894, and dried in cocks. At time of cutting it was a little past full bloom, many of the heads beginning to seed at the base. The experiment was apparently normal with all four animals. They all ate up the feed completely and seemed to be hungry. Tables 41 and 42, which follow, give the details of the experiment.

TABLE 41.
Composition of Feeding Stuffs and Feces.

KIND OF MATERIAL.	Lab'ty No.	Water.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Feeding Stuff.</i>		%	%	%	%	%	%	%
Scarlet clover* hay,	1418	13.9	14.1	1.8	31.6	31.3	7.3	78.8
<i>Feces.</i>								
Sheep A, - -	1419	5.4	10.5	2.1	29.7	43.6	8.7	85.9
Sheep B, - -	1420	6.9	10.6	2.1	27.6	42.8	10.0	83.1
Sheep C, - -	1421	6.3	10.4	2.3	32.0	39.8	9.2	84.5
Sheep D, - -	1422	5.5	11.1	2.1	31.1	41.3	8.9	85.6

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 42.
Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.

	Weight.	Protein. N. $\times$ 6.25.	Fat.	Nit.- free Ext	Fiber.	Ash.	Organic Matter.
<i>Eaten in 5 Days.</i>	Grams*	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, - - -	3300	427	55	958	948	221	2388
Sheep B, - - -	3300	427	55	958	948	221	2388
Sheep C, - - -	3300	427	55	958	948	221	2388
Sheep D, - - -	3300	427	55	958	948	221	2388
<i>Feces for Five Days.</i>							
Sheep A, - - -	1469	154	31	436	641	128	1262
Sheep B, - - -	1455	154	31	401	623	145	1209
Sheep C, - - -	1433	149	33	459	570	132	1211
Sheep D, - - -	1359	151	29	422	561	121	1163
<i>Amounts Digested.</i>							
Sheep A, - - -	1831	273	24	522	307	93	1126
Sheep B, - - -	1845	273	24	557	325	76	1179
Sheep C, - - -	1867	278	22	499	378	89	1177
Sheep D, - - -	1941	276	26	536	387	100	1225
<i>Per Cent. Digested.</i>		%	%	%	%	%	%
Sheep A, - - -	—	63.9	43.6	54.5	32.4	42.1	47.2
Sheep B, - - -	—	63.9	43.6	58.1	34.3	34.4	49.4
Sheep C, - - -	—	65.1	40.0	52.1	39.9	40.3	49.3
Sheep D, - - -	—	64.6	47.3	55.9	40.8	45.3	51.3
Average, - - -	—	65.4	43.6	55.2	36.9	40.5	49.3

* One pound contains 454 grams.

TABLE 43.

*Summary of Results of Digestion Experiments with Sheep Here-
with Reported Upon—Percentages of Total Nutrients
of Food Actually Digested.*

KIND OF FOOD.	Current No. of Experiment.	Sheep.	Protein. N. $\times$ 6.25.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Organic Matter.
			%	%	%	%	%	%
Wheat bran 4 oz., corn meal } 12 oz., and hay 1 lb. The wide ration of sheep feeding experiment, pp. 92-106, this Report.	{ 1 4 4	{ B, D, B, D,	48.0 62.1 57.6 52.2	60.6 72.9 69.1 71.2	71.5 76.1 80.1 77.7	45.6 59.6 60.7 55.2	5.9 26.6 32.0 27.4	62.7 70.8 72.8 69.6
Avg. 2 experiments and 4 tests,	—	—	55.0	68.5	76.4	55.3	23.0	69.0
Wheat bran 4 oz., corn meal } 1 oz., linseed meal 3 oz., oat and pea meal 8 oz., hay 1 lb. The narrow ration of sheep feeding experiment, pp. 92-106, this Report.	{ 2 2 3 3	{ B, D, B, D,	73.5 71.2 77.1 71.6	64.7 71.2 72.8 73.4	73.8 74.9 77.0 73.6	59.0 60.8 69.2 61.1	26.8 28.2 40.9 20.9	70.1 70.9 75.0 70.3
Avg. 2 experiments and 4 tests,	—	—	73.4	70.5	74.8	62.5	29.2	71.6
Scarlet clover fodder, fed } green, - - - - - }	{ 5 5 5	{ A, B, D,	76.7 77.5 77.2	67.3 62.9 60.3	74.5 74.9 74.1	54.1 57.9 56.2	55.0 55.9 57.4	68.5 69.8 69.1
Avg. 1 experiment and 3 tests,	—	—	77.1	66.5	74.5	56.1	56.1	69.1
Scarlet clover hay, - - - }	{ 10 10 10 10	{ A, B, C, D,	63.9 63.9 65.1 64.6	43.6 43.6 40.0 47.3	54.5 58.1 52.1 55.9	32.4 34.3 39.9 40.8	42.1 34.4 40.3 45.3	47.2 49.4 49.3 51.3
Avg. 1 experiment and 4 tests,	—	—	65.4	43.6	55.2	36.9	40.5	49.3
Barley fodder, fed green, - }	{ 6 6	{ A, B,	69.3 71.4	61.2 63.1	69.3 76.3	49.0 63.6	49.7 62.2	62.2 70.7
Avg. 1 experiment and 2 tests,	—	—	70.4	62.2	72.8	56.3	55.9	56.5
Barley and pea fodder, - - }	{ 7 7	{ C, D,	81.1 73.2	64.8 54.5	67.0 55.8	49.3 37.6	58.4 33.9	65.1 55.2
Avg. 1 experiment and 2 tests,	—	—	77.2	59.7	61.4	43.5	46.2	60.2
Rowen hay, mixed grasses, } chiefly Kentucky bluegrass, }	{ 8 8 8 8	{ A, B, C, D,	70.1 67.6 70.2 68.4	50.5 44.0 45.6 44.6	67.7 62.9 62.6 67.0	66.2 65.4 66.1 68.2	54.8 49.4 55.5 52.4	66.7 63.5 64.1 66.3
Avg. 1 experiment and 4 tests,	—	—	69.1	46.2	65.1	66.5	53.0	65.2
Rowen hay, mostly timothy, }	{ 9 9 9 9	{ A, B, C, D,	66.1 69.4 68.2 68.3	50.8 48.2 48.7 50.3	64.9 60.9 63.5 64.3	65.2 62.0 65.2 73.4	50.8 74.6 53.2 46.9	64.4 62.0 64.1 67.2
Avg. 1 experiment and 4 tests,	—	—	68.0	49.5	63.4	66.5	56.4	64.4

FUEL VALUES OF DIGESTED NUTRIENTS IN
EXPERIMENTS IN SHEEP.

BY W. O. ATWATER AND CHAS. D. WOODS.



In connection with the digestion experiments with sheep described in the preceding paper (pp. 107-122), the heats of combustion of the feeding stuffs and feces were determined by use of the bomb calorimeter, with the purpose of getting light upon the potential energy or fuel value of the digested material.*

The problem is, however, not as simple as these brief statements imply. Indeed it is extremely complex, but for the present purpose it will suffice to say that while most of the unconsumed material of the food leaves the body in the undigested food residue of the feces, a small portion escapes in urea and other substances of the urine. These last substances come from the digested material of the food; they are digested material which has not been completely consumed, and they contain potential energy. If, therefore, we are to find how much of the potential energy of the food has been set free in the body we must subtract from the total energy of the food, the sum of the amounts excreted in both feces and urine. The remainder is taken as the measure of the actual fuel value of the food.

Food has two chief uses. The first is to build up the materials of the body and repair their wastes, the second is to yield energy in the form of heat to keep it warm and strength for its work. The nutritive ingredients or nutrients of the food make blood and muscle, bone and milk and other tissues and fluids of the body and replace them as they are used up. But only the portions which are actually digested serve these purposes. Hence to learn the nutritive value of food we endeavor to find how much of each of its nutrients is digested and thus made useful for building and repair. To do this we learn how much of

* The bomb calorimeter is described in a succeeding article, page 135. Brief explanations of potential energy and fuel values are given on pages 43 and 44.

nutrients was contained in the food eaten and how much was left in the undigested residue. The difference is taken as the measure of the amount digested. In the same way, it is the potential energy of the digested material which is made available to the body in the forms of heat and muscular power. The energy of the undigested material is lost to the body. To learn how much of the energy of the food is available we must find how much potential energy was contained in the food eaten and how much is left in the residues not used in the body. The difference will be the amount set free and made available for fuel.

The potential energy of the food and the unconsumed residues is learned by burning the materials in the calorimeter and measuring the heat produced. This method has been followed in connection with the digestion experiments referred to.

The experiments here described are, so far as the writers know, the first attempt in this direction.* The results are far from being all that could be desired. We have not yet found a perfectly satisfactory method for determination of the heat of combustion of the solid matters of the urine, though we hope for better success in due time. A number of collateral subjects call for study, some of which are already entered upon. The purpose here is simply to report some of the first results obtained.

The much needed study of the general subject requires the taking into account of the total income and outgo of the body as expressed in terms of matter and of energy. This is the purpose of the respiration calorimeter which is now being elaborated by coöperation of the Station in the chemical laboratory of Wesleyan University, to which reference was made in the last Annual Report of this Station.†

The purpose of the present article is to record some of the observations already made. An explanation of the way in which the principal data are obtained is given with the details of the latter in the case of experiment No. 1. For the other experiments only the data are cited. The results of all the experiments are summarized in table 44.

* Prof. H. P. Armsby, of the Pennsylvania Experiment Station, has conducted a series of feeding experiments in which the heats of combustion of food and residues were determined by one of us with the calorimeter used in the experiments here described, but the results are not yet published.

† Report for 1893, page 16.

DIGESTION EXPERIMENT NO. I.

(See page 109, this Report.)

Bran, corn meal and hay.

In this experiment three different feeding stuffs were employed. The composition of each was determined by analyses. Their fuel values were determined by combustion in the bomb calorimeter, and were also calculated from the chemical composition. The methods employed for calculating from chemical composition are those explained in the Report of this Station for 1890, pages 174-181, and are also referred to on page 43 of this Report. The fuel values as obtained in the two ways were somewhat different, as appears from the following figures:

Fuel Values—Calories per Gram of Water-free Substance.

	Laboratory No.	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Bran, - - - -	1301	4.430	4.585
Corn meal, - - - -	1300	4.460	4.520
Hay, - - - -	1325	4.245	4.515

The fuel value of the total food eaten in five days was obtained by multiplying the number of grams of food by the fuel value per gram as determined by the bomb calorimeter.

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Fuel value of bran, - - - - - 2,360 Calories.

Fuel value of corn meal, - - - - - 6,725 Calories. •

Fuel value of hay, - - - - - 9,345 Calories.

Total fuel value of food eaten, - - - - - 18,430 Calories.

The feces were burned in the bomb calorimeter. Multiplying the number of grams by the fuel value of one gram gives the figures which follow:

Sheep B, - - - - - 7,600 Calories.

Sheep D, - - - - - 5,920 Calories.

When protein is burned in the calorimeter it is completely oxidized, the carbon being burned to carbon dioxide and the hydrogen to water. The nitrogen is left uncombined. When protein is consumed in the body the oxidation is not complete. The nitrogen is left in urea, uric acid and other allied compounds, all of which contain carbon and hydrogen, together with some oxygen. In estimating the actual fuel value of the digested ingredients which an animal can utilize, allowance must be made for these unconsumed residual products, which are excreted by the kidneys. Urea is usually the most abundant of these excretory products, and it is here assumed that all of the nitrogen of the digested protein is excreted as urea. The fuel value of urea as determined by Stohmann and Berthelot is 2.53 Calories per gram.*

The method used in the calculations here has been as follows: Urea (CON_2H_4) contains 46.67 per cent. of nitrogen. Hence nitrogen multiplied by the factor 2.143 equals urea. The protein as here estimated is the nitrogen

* See Bulletin No. 21 of the Office of Experiment Stations, U. S. Department of Agriculture, on Methods and Results of Investigations of the Chemistry and Economy of Food, for a more detailed discussion of the subject.

multiplied by 6.25. Hence dividing the protein by 6.25 and multiplying the quotient by 2.143 gives the equivalent urea. Assuming that all of the digested protein is excreted as urea, the number of grams of urea multiplied by 2.53, the fuel value of one gram of urea, gives the total fuel value of the urea equivalent to the digested protein. But $(\text{protein divided by } 6.25) \times 2.143 \times 2.53 = \text{protein} \times .87$. This last expression, $\text{protein} \times .87$, therefore, represents the fuel value of the urea equivalent to the digestible protein. The fuel values of urea equivalent to the protein in this experiment and the total unused fuel value (the sum of the fuel values of the feces and of the urea equivalent to the protein) are as follows:

Fuel Values of Urea Equivalent to Digested Protein.

Sheep B, - - - - -	215 Calories.
Sheep D, - - - - -	280 Calories.

Total Unused Fuel Value (Feces Plus Urea Equivalent).

Sheep B, - - - - -	7,815 Calories.
Sheep D, - - - - -	6,200 Calories.

The available fuel value of the digested nutrients is the difference between the fuel value of the total food eaten and the total unused fuel value. Omitting details of calculations the results follow. With these results are given for the sake of comparison those obtained by taking the grams of nutrients digested as stated on page 110, and multiplying the protein by 5.5, the carbohydrates by 4.1 and the fats by 9.3 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep B, - - - - -	10,625 Calories.	10,615 Calories.
Sheep D, - - - - -	12,050 Calories.	12,230 Calories.

Dividing the fuel value of the digested nutrients by the fuel value of the food eaten gives the per cent. of total fuel value which thus becomes available. These percentages follow. With them are the percentages of digestible protein, taken from the Report of this experiment on page 110.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep B, 48.0 per cent. of total protein and 57.6 per cent. of total fuel value.
 Sheep D, 62.1 per cent. of total protein and 66.4 per cent. of total fuel value.

DIGESTION EXPERIMENT NO. 2.

(See page 111, this Report.)

Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.

Calories per Gram of Water-free Substance.

	Laboratory No.	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Wheat bran, - - -	1304	4.405	4.585
Linseed meal, - - -	1302	4.690	4.735
Oat and pea meal, - - -	1303	4.470	4.530
Hay, - - - - -	1426	4.255	4.505

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Fuel value of bran, - - - - -	2,370 Calories.
Fuel value of linseed meal and corn meal, - - - - -	2,465 Calories.
Fuel value of oat and pea meal, - - - - -	4,540 Calories.
Fuel value of hay, - - - - -	9,375 Calories.
Total fuel value of food eaten, - - - - -	18,750 Calories.

Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.

Sheep B, - - - - -	6,150 Calories.
Sheep D, - - - - -	5,940 Calories.

Fuel Value of Urea Equivalent to Digested Protein.

Sheep B, - - - - -	680 Calories.
Sheep D, - - - - -	655 Calories.

Total Unused Fuel Value (Feces Plus Urea Equivalent).

Sheep B, - - - - -	6,830 Calories.
Sheep D, - - - - -	6,595 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep B, - - - - -	11,785 Calories.	11,920 Calories.
Sheep D, - - - - -	11,975 Calories.	12,155 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep B, 73.5 per cent. of total protein and 63.6 per cent. of total fuel value.
 Sheep D, 71.2 per cent. of total protein and 64.8 per cent. of total fuel value.

DIGESTION EXPERIMENT NO. 3.

(See page 112, this Report.)

*Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.**Calories per Gram of Water-free Substance.*

	Laboratory No.	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Wheat bran, - - -	1338	4.376	4.530
Linseed meal and corn meal, - - -	1339	4.685	4.750
Oat and pea meal, - - -	1340	4.445	4.515
Hay, - - - - -	1327	4.235	4.520

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Wheat bran, - - - - -	2,345 Calories.
Linseed meal and corn meal, - - - - -	2,395 Calories.
Oat and pea meal, - - - - -	4,535 Calories.
Hay, - - - - -	9,380 Calories.
Total fuel value of food eaten, - - - - -	18,655 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep B, - - - - -	12,540 Calories.	12,390 Calories.
Sheep D, - - - - -	12,045 Calories.	11,895 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep B, 57.6 per cent. of total protein and 67.9 per cent. of total fuel value.

Sheep D, 52.2 per cent. of total protein and 65.2 per cent. of total fuel value.

DIGESTION EXPERIMENT NO. 5.

(See page 114, this Report.)

Scarlet fodder, fed green.

Calories per Gram of Water-free Substance.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Scarlet clover, average, - - -	4.190	4.390

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Sheep A and B, - - - - - 15,875 Calories.

Sheep D, - - - - - 12,700 Calories.

Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.

Sheep A, - - - - - 5,340 Calories.

Sheep B, - - - - - 5,240 Calories.

Sheep D, - - - - - 4,200 Calories.

Fuel Value of Urea Equivalent to Digested Protein.

Sheep A, - - - - - 425 Calories.

Sheep B, - - - - - 430 Calories.

Sheep D, - - - - - 340 Calories.

Total Unused Fuel Value (Feces Plus Urea Equivalent).

Sheep A, - - - - - 5,765 Calories.

Sheep B, - - - - - 5,670 Calories.

Sheep D, - - - - - 4,540 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep A, - - - - -	9,730 Calories.	10,110 Calories.
Sheep B, - - - - -	9,860 Calories.	10,205 Calories.
Sheep D, - - - - -	7,860 Calories.	8,160 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep A, 76.7 per cent. of total protein and 63.7 per cent. of total fuel value.

Sheep B, 77.5 per cent. of total protein and 64.3 per cent. of total fuel value.

Sheep D, 77.2 per cent. of total protein and 64.3 per cent. of total fuel value

DIGESTION EXPERIMENT NO. 6.

(See page 115, this Report).

*Barley fodder fed green.**Calories per Gram of Water-free Substance.*

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Barley fodder, average, - - -	4.135	4.520

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Sheep A, - - - - - 13,735 Calories.

Sheep B, - - - - - 14,360 Calories.

Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.

Sheep A, - - - - - 5,520 Calories.

Sheep B, - - - - - 4,515 Calories.

Fuel Value of Urea Equivalent to Digested Protein.

Sheep A, - - - - - 280 Calories.

Sheep B, - - - - - 305 Calories.

Total Unused Fuel Value (Feces Plus Urea Equivalent).

Sheep A, - - - - - 5,800 Calories.

Sheep B, - - - - - 4,820 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep A, - - - - -	7,415 Calories.	7,935 Calories.
Sheep B, - - - - -	8,765 Calories.	9,540 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep A, 69.3 per cent. of total protein and 57.8 per cent. of total fuel value.

Sheep B, 71.4 per cent. of total protein and 66.4 per cent. of total fuel value.

DIGESTION EXPERIMENT NO. 7.

(See page 116, this Report.)

*Barley and pea fodder, fed green.**Calories per Gram of Water-free Substance.*

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Barley and pea fodder, average, - -	4.255	4.570

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Sheep C, - - - - - 12,385 Calories.

Sheep D, - - - - - 10,435 Calories.

Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.

Sheep C, - - - - - 4,540 Calories.

Sheep D, - - - - - 4,975 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep A, - - - - -	9,280 Calories.	9,905 Calories.
Sheep B, - - - - -	8,790 Calories.	9,295 Calories.
Sheep C, - - - - -	9,865 Calories.	10,500 Calories.
Sheep D, - - - - -	10,225 Calories.	10,750 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep A, 69.1 per cent. of total protein and 60.9 per cent. of total fuel value.
 Sheep B, 65.9 per cent. of total protein and 57.1 per cent. of total fuel value.
 Sheep C, 66.9 per cent. of total protein and 58.1 per cent. of total fuel value.
 Sheep D, 68.6 per cent. of total protein and 59.5 per cent. of total fuel value.

DIGESTION EXPERIMENT NO. 9.

(See page 119, this Report.)

*Rowen hay, mostly timothy.**Calories per Gram of Water-free Substance.*

	Laboratory No.	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Rowen, - - - - -	1399	4.270	4.650

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Sheep A, B and C, each, - - - - - 17,165 Calories.
 Sheep D, - - - - - 15,850 Calories.

Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.

Sheep A, - - - - - 6,640 Calories.
 Sheep B, - - - - - 6,790 Calories.
 Sheep C, - - - - - 6,805 Calories.
 Sheep D, - - - - - 5,850 Calories.

Fuel Value of Urea Equivalent to Digested Protein.

Sheep A, - - - - - 345 Calories.
 Sheep B, - - - - - 360 Calories.
 Sheep C, - - - - - 355 Calories.
 Sheep D, - - - - - 335 Calories.

Total Unused Fuel Value (Feces Plus Urea Equivalent).

Sheep A, - - - - - 6,985 Calories.
 Sheep B, - - - - - 7,150 Calories.
 Sheep C, - - - - - 7,160 Calories.
 Sheep D, - - - - - 6,185 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep A, - - - - -	9,470 Calories.	10,180 Calories.
Sheep B, - - - - -	9,115 Calories.	10,015 Calories.
Sheep C, - - - - -	9,445 Calories.	10,005 Calories.
Sheep D, - - - - -	9,080 Calories.	9,605 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep A, 66.1 per cent. of total protein and 59.3 per cent. of total fuel value.
 Sheep B, 69.4 per cent. of total protein and 58.6 per cent. of total fuel value.
 Sheep C, 68.2 per cent. of total protein and 58.3 per cent. of total fuel value.
 Sheep D, 68.3 per cent. of total protein and 60.9 per cent. of total fuel value.

DIGESTION EXPERIMENT NO. 10.

(See page 120, this Report.)

*Scarlet clover hay, field cured.**Calories per Gram of Water-free Substance.*

	Laboratory No.	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Scarlet clover hay, - -	1418	4.090	4.375

Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.

Sheep A, B, C and D, each, - - - - - 11,395 Calories.

Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.

Sheep A, - - - - - 6,330 Calories.
 Sheep B, - - - - - 6,175 Calories.
 Sheep C, - - - - - 6,085 Calories.
 Sheep D, - - - - - 5,880 Calories.

Fuel Value of Urea Equivalent to Digested Protein.

Sheep A, B, C and D, each, - - - - - 240 Calories.

Total Unused Fuel Value (Feces Plus Urea Equivalent).

Sheep A, - - - - - 6,570 Calories.
 Sheep B, - - - - - 6,415 Calories.
 Sheep C, - - - - - 6,325 Calories.
 Sheep D, - - - - - 6,120 Calories.

Available Fuel Value of Digested Nutrients.

	As Calculated from Analysis.	As Determined by Bomb Calorimeter.
Sheep A, - - - - -	4,740 Calories.	4,825 Calories.
Sheep B, - - - - -	4,960 Calories.	4,980 Calories.
Sheep C, - - - - -	4,940 Calories.	5,070 Calories.
Sheep D, - - - - -	5,160 Calories.	5,275 Calories.

Digested Protein and Available Fuel Value of Food Eaten.

Sheep A, 63.9 per cent. of total protein and 42.4 per cent. of total fuel value.
 Sheep B, 63.9 per cent. of total protein and 43.7 per cent. of total fuel value.
 Sheep C, 65.1 per cent. of total protein and 44.5 per cent. of total fuel value.
 Sheep D, 64.6 per cent. of total protein and 46.3 per cent. of total fuel value.

TABLE 44.

Summary.

FEEDING STUFFS.	Current No. of Experiment.	Sheep.	FUEL VALUE OF DIGESTED NUTRIENTS.		Digested Protein.	Available Fuel Value.
			Calculated from Analysis.	Determined by Bomb Calorimeter.		
			Calories.	Calories.	%	%
Bran, corn meal and hay, - - -	1	B	10,625	10,615	48.0	57.6
Bran, corn meal and hay, - - -	1	D	12,050	12,230	62.1	66.4
Bran, corn meal and hay, - - -	4	B	12,540	12,390	57.6	67.9
Bran, corn meal and hay, - - -	4	D	12,045	11,895	52.2	65.2
Average, - - - - -	—	—	—	—	55.0	64.3
Wheat bran, linseed meal, oat and pea meal, hay, - - - - -	{ 2	B	11,785	11,920	73.5	63.6
Wheat bran, linseed meal, oat and pea meal, hay, - - - - -	{ 2	D	11,975	12,155	71.2	64.8
Wheat bran, corn meal, linseed meal, oat and pea meal, hay, - - - - -	{ 3	B	12,585	13,120	77.1	70.3
Wheat bran, corn meal, linseed meal, oat and pea meal, hay, - - - - -	{ 3	D	11,850	12,200	71.6	65.4
Average, - - - - -	—	—	—	—	73.4	66.0
Scarlet clover, fed green, - - -	5	A	9,730	10,110	76.7	63.7
Scarlet clover, fed green, - - -	5	B	9,860	10,205	77.5	64.3
Scarlet clover, fed green, - - -	5	D	7,860	8,160	77.2	64.3
Average, - - - - -	—	—	—	—	77.1	64.1
Barley fodder, fed green, - - -	6	A	7,415	7,935	69.3	57.8
Barley fodder, fed green, - - -	6	B	8,765	9,540	71.4	66.4
Average, - - - - -	—	—	—	—	70.4	62.1
Barley and pea fodder, fed green, - - -	7	C	7,025	7,460	81.1	60.2
Barley and pea fodder, fed green, - - -	7	D	5,055	5,150	73.2	49.4
Average, - - - - -	—	—	—	—	77.2	54.8
Rowen hay, mixed grasses, - - -	8	A	9,280	9,905	69.1	60.9
Rowen hay, mixed grasses, - - -	8	B	8,790	9,295	65.9	57.1
Rowen hay, mixed grasses, - - -	8	C	9,865	10,500	66.9	58.1
Rowen hay, mixed grasses, - - -	8	D	10,225	10,750	68.9	59.5
Average, - - - - -	—	—	—	—	67.7	58.9
Rowen hay, mostly timothy, - - -	9	A	9,470	10,180	66.1	59.3
Rowen hay, mostly timothy, - - -	9	B	9,115	10,015	69.4	58.6
Rowen hay, mostly timothy, - - -	9	C	9,445	10,005	68.2	58.3
Rowen hay, mostly timothy, - - -	9	D	9,080	9,665	68.3	60.9
Average, - - - - -	—	—	—	—	68.0	59.3
Scarlet clover hay, field cured, - - -	10	A	4,740	4,825	63.9	42.4
Scarlet clover hay, field cured, - - -	10	B	4,960	4,980	63.9	43.7
Scarlet clover hay, field cured, - - -	10	C	4,940	5,070	65.1	44.5
Scarlet clover hay, field cured, - - -	10	D	5,160	5,275	64.6	46.3
Average, - - - - -	—	—	—	—	64.4	44.2

A NEW FORM OF BOMB CALORIMETER AND DETERMINATIONS OF HEATS OF COMBUSTION.

BY W. O. ATWATER AND CHAS. D. WOODS.



THE BOMB CALORIMETER.

During the past five years the reports and bulletins of this Station have contained frequent reference to the fuel values of food materials and the need of more definite information regarding not only the potential energy of food, but also the more general subject of the transformation of energy in the living organism.*

The later development of experimental science has given us clearer ideas not only of the chemical, but also of the physical changes that take place in the animal and in the plant. To these processes it has become customary to apply the term metabolism. The processes of metabolism in the body are of two definite but closely allied kinds—the metabolism of matter and the metabolism of energy. It is commonly assumed that these two processes conform, the one to the law of the conservation of matter and the other to that of the conservation of energy. Exactly this form of statement is not usual, but the principles thus enunciated have been more or less definitely assumed by writers and experimenters during the last twenty years or more. The bringing of the metabolic processes into line with these two fundamental laws helps greatly toward simplifying the whole subject, clearing up details that have been obscure, and placing the doctrine of nutrition upon a rational and simple basis. In the light of these laws many of the results of experimenting are more easily interpreted, imperfections in plan and errors in execution of past experimenting are brought out, and the ways in which the unsolved problems before us may best be studied are laid open. Experimenter, teacher, and student alike are helped by such a coördination of principles. At the same time the theory of nutrition thus becomes plainer to the practical man. He can understand it

* See, especially, Report for 1896, p. 174.

more easily if it is put in terms of "flesh formers" and "fuel values" than if he must consider protein, fats, and carbohydrates in the ways which have become so generally current.

Food has two chief functions—to build tissue and serve as fuel. In the building of tissue from food and in the constant breaking up and repair of tissue we have to do with the metabolism of matter. In the service of food and of tissue material as fuel, to yield heat and muscular power, we have to do with the metabolism of energy. The protein compounds are the tissue formers. The fats and the carbohydrates are the chief fuel ingredients; but protein compounds also serve as fuel. In this service as fuel the nutrients replace each other in proportion to their potential energy. The economy of food in nutrition requires sufficient protein for the formation of tissue and sufficient energy for supplying heat and strength. The fuel value of food is thus one of the two chief factors of its value for nutriment.

The fat of the food is stored as fat in the body. The protein and carbohydrates of the food are transformed into body fat. The fuel value of the food thus becomes an indication of its capacity for fat formation.

The fat of the body is its reserve store of fuel. The fuel value of the fats is more than twice as great, weight for weight, as that of the protein or carbohydrates. Fat is body fuel in its most concentrated form. Therein lies the economy of nature in the storage of fat in the body.

Of course the whole doctrine of nutrition is not as simple a matter as these statements would imply, but they do represent its fundamental principles. One important part of the problem is the source of intellectual energy. Doubtless this comes, in some way, from the food, but what it is and how it is produced and what food materials are most efficient for its production are questions that the experimental science of to-day are far from answering.

In the metabolism of matter and energy we have the foundation of the theory of nutrition, the starting point of experimental inquiry, and the means of simplifying the theories which we have to teach. It is thus clear that the experimenter who will study thoroughly the laws of nutrition and the uses and the nutritive values of food must have a means for determining the potential energy of the ingredients of the food and of the compounds of the body which are formed from them. Since this potential energy is measured

by the heat developed when the substances are burned with oxygen he may employ a method for determining the amount of heat thus developed.

But it is not the physiological chemist alone to whom the method and apparatus for measuring heats of combustion is essential. Inquiry in this special field is of fundamental importance in physical chemistry generally, and research has demonstrated its necessity for that understanding of the molecular structure of compounds which has become one of the most important factors of the development of those branches of chemical science to which the terms "organic" and "theoretical" are commonly applied. And finally, the chemical technologist, who is endeavoring to learn the values of coal and other fuel materials for heating, experiences the necessity of a means for determining their heats of combustion. Various forms of calorimetric apparatus have been devised for this purpose.* The Stohmann calorimeter,† which is a modification of that of Thompson, was employed for the studies of heats of combustion by Dr. H. B. Gibson, which were described in the report of this Station for 1890.

In the combustions by the Thompson-Stohmann method the oxygen is obtained from potassium chlorate. Considerable time is required for the determination, but the chief difficulty with this method is that the combustion is not always complete.

THE BERTHELOT BOMB CALORIMETER.

Berthelot has devised an apparatus‡ and, with the assistance of Vieille and others, has developed a method for the use of oxygen under high pressure. The apparatus consists essentially of a steel bomb lined with platinum, within which the substance is burned. The bomb is immersed in water contained in a metal cylinder; this calorimeter cylinder is placed with its contents inside of concentric cylinders containing air and water. The heat developed

* See discussion of the general subject of metabolism of energy in the body and descriptions of calorimeters in Bulletin 21 of the Office of Experiment Stations of the U. S. Department of Agriculture, from which portions of the statements herewith regarding bomb calorimeters are taken. The engravings of the calorimeter beyond are from the same publication and are used here by courtesy of the Department.

† This apparatus is described in the Bulletin just referred to. See also the original description by Stohmann, with diagram; Landw. Jahrbücher, 13, 1884, 513. The apparatus is pictured in the Century Magazine for July, 1887.

‡ For descriptions see Berthelot, Ann. Chim. Phys. (5), 23, 160; Berthelot & Vieille, *ibid.*, (6) 6, 546 Berthelot, *Traité pratique de calorimétrie chimique*, Paris, 1893, p. 128, and, for an especially clear account of the apparatus and method, Stohmann, Jour. f. prak. Chem., 147 (N. F. 39), 1889, 503. An engraving of the bomb with a brief description may be found in Fres. Zeitsch. Anal. Chem., 1893, 77. A Berthelot apparatus employed by Stohmann was obtained from Golaz in Paris, who made it in accordance with Berthelot's directions. Its cost, with accessories, including compression pump, etc., not far from \$1,200. Aside from those used in Berthelot's laboratory and the one made for Stohmann, extremely few have been made.

is measured by the rise in temperature of the water, due allowance being made for the heat absorbed by the metal of the apparatus and for that introduced in igniting the substance by an electric current and developed by the oxidation of an iron wire through which the current is passed, and in the formation of a small amount of nitric acid. The reactions are simple, the oxidation of the compounds in completing the determination requires a comparatively short time, and the results are very satisfactory. The only drawback is the great cost of the apparatus, which is due to the large amount of platinum employed in its construction. It is doubtless because of this that the bomb, which is most useful for its purpose and would be highly prized in many laboratories, has not come into common use.

The bomb calorimeter was first used by Berthelot in measuring the heats of combustion of gases by detonation. The gas to be burned was mixed with the exact amount of oxygen required, or a slight excess, at ordinary atmospheric pressure within the bomb and ignited by the passage of an electric spark. Gases were easily burned in this way, but the combustion of solids was impracticable. Attempts were made to remedy the difficulty with solids by intimately mixing them with potassium chlorate and as good results were obtained as in the Thompson-Stohmann method. Berthelot and Vieille* found later,† however, that when oxygen was introduced under a pressure of from 7 to 25 atmospheres, the combustion was complete with all organic substances even when no potassium chlorate was added.

The bomb originally employed by Berthelot was in the shape of a cylinder, with hemispherical ends and divided in two parts, one of which screwed into the other. It was made of steel with the interior lined with gold by electro-plating.

The later and permanent form of Berthelot's bomb is cylindrical with a rounded bottom and flat cover. It is made of steel with a heavy lining of platinum. The size may vary. In the one made by Golaz for Stohmann the diameter is approximately 10 centimeters and the height to the upper surface of the cover about 13 centimeters; the walls are somewhat over a centimeter in thickness. It contains 2,717 grams of steel and 1,233.3 grams

* Ann. Chim. Phys., (6) 6, 546.

† In 1885. The principle was discovered and investigated by Frankland in 1864 and 1868. See investigations by him "On the combustion of iron in compressed oxygen," Jour. Chem. Soc. 11., 1864; 52. "On the combustion of gases under pressure," Brit. Assoc. Rep. XXXVIII., 1868 (*Sec. I.*); 37. "On the combustion of hydrogen and carbonic oxide in oxygen under great pressure," Proc. Roy. Soc. XVI., 1868; 419.

of platinum. The internal capacity is about 300 cubic centimeters and it holds, under a pressure of 24 atmospheres, 7 liters, or, in round numbers, 10 grams, of oxygen. The cover fits into the top of the cylinder after the manner of a stopper. It is pressed in and held very tightly by an outer cap or collar which screws on to the outside of the cylinder at the top. The fittings have to be made with the greatest care in order to prevent the escape of gas. The material to be burned is shaped into a small cake by means of a powerful press and is held in a platinum capsule. This capsule is sustained by a platinum wire which is fastened to the under side of the cover. Another platinum wire passes through the cover, from which it is insulated by gutta percha, or other appropriate material. These two wires are so arranged that they are easily connected by a piece of fine iron wire hanging over the substance to be burned in the platinum capsule. An electric current passed through the platinum wire heats the iron wire to a temperature where it burns in the oxygen and, melting, falls upon the substance so as to ignite it. An arrangement at the top of the cover provides for admitting the oxygen. The oxygen is introduced either with the aid of a compression pump, or, more conveniently, from iron or steel cylinders, in which it is held under sufficient pressure. Both Berthelot and Stohmann use such cylinders without the aid of a pump. Experience has shown that it is desirable to have fully three times as much oxygen present as is theoretically necessary for the combustion.

The quantity of water in which the bomb is immersed is generally about 2 liters. It is contained in a calorimeter cylinder of brass or other metal. A stirrer, not easily described without a diagram, plays between the bomb and the cylinder in such a way as readily to mix the water and insure uniform temperature after the combustion. The outer cylinders which are employed by Berthelot and Stohmann to protect the apparatus from gain or loss by heat outside, as above described, are made of copper. They find that two concentric cylinders so arranged as to hold a layer of water between them, the inner being large enough to leave a considerable air space around the calorimeter cylinder, suffice for accurate work.

In Stohmann's laboratory the arrangements to insure accuracy are quite elaborate. The work is done in a basement room surrounded by very thick walls of stone. Special devices are

employed to keep the temperature of the room exactly constant. The stirrer is moved by a small motor, which is so regulated as to make the movement the same for all determinations. Berthelot uses a motor for the stirring, but conducts the combustion in the laboratory rooms where other work is done and without special arrangements to insure uniform temperature.

The Berthelot bomb calorimeter serves its purpose admirably. It is comparatively simple, easily handled, and does not get out of order when properly cared for. Practically all kinds of ordinary organic compounds are completely oxidized when the proper excess of oxygen is used at an initial pressure of 25 atmospheres. With an accurate thermometer the rise in temperature of the water is measured with great accuracy. The corrections, of which the chief is the thermal water equivalent of the apparatus, are not particularly difficult to determine. The skill and care required in the manipulation are not beyond any thoroughly expert operator, and the results are very satisfactory indeed, as may be seen by comparing those obtained by Berthelot and Stohmann in determining the heats of combustion of the same material in their respective laboratories.

The steel of which the bomb is made is especially exposed to corrosion. Berthelot protects the outside of the bomb by plating with nickel which serves the purpose very well, as water and air are practically the only corrosive agents to which it is exposed. But with the interior the case is very different. The oxygen at high pressure is very active in itself. The carbon, sulphur, and phosphorus of the substances burned are completely oxidized, and carbonic, sulphuric and phosphoric acids are formed. Indeed, Berthelot has shown that the apparatus may be used for determining carbon, sulphur and phosphorus in these forms. More or less of the free nitrogen which is mingled with the oxygen used in the combustion and perhaps, at times, some of the nitrogen of the substance burned is oxidized and forms nitric acid. It is necessary that the inner surface be covered with some substance which will resist these acids as well as the oxygen. Such materials are easily found, but the practical difficulty has been to find an inexpensive lining which will insure permanent protection to the steel. In Berthelot's first bomb, electro-plating with platinum was tried, but the platinum soon began to scale off. After a few combustions gold was substituted for platinum and with better success, but it has not been used with oxygen under

pressure. The outcome of the experience was the use of a lining of platinum one-half millimeter in thickness.

THE BOMB CALORIMETERS OF MAHLER AND OF HEMPEL.

Various modifications of Berthelot's apparatus have been devised especially to obviate the difficulty of expensive lining. Mahler uses a bomb of forged steel with enamel lining.* The cylinder is somewhat narrowed at the top and the cover is screwed directly upon it, the junction being made tight by a washer of lead. The enamel is easily put on or replaced, and it is stated that a single coating has been used for 300 combustions without injury. I have understood, however, that the enamel is apt to scale off in constant use. The form described by Mahler has an internal capacity of 600 cubic centimeters or nearly double that of Berthelot's bomb, as above described.

Prof. Hempel of Dresden uses, for determination of heats of combustion of coal, a simple bomb of steel without lining. The principle, like that of Mahler's form, is the same as that of Berthelot. The closure is by a "head piece" which screws into the neck of the bomb. It suffices very well for technical purposes but is not recommended for scientific use.†

THE BOMB CALORIMETER HERE USED.

In accordance with suggestions by one of us during a sojourn in Dresden, Prof. Hempel most kindly had a bomb made by the mechanics who make the bombs of his devising just referred to and lined, by Heraeus of Hanau, with a thin sheet of platinum. Through Prof. Hempel's pains-taking care added to his inventive skill and his peculiarly thorough familiarity with the whole subject, an apparatus was obtained which has proved most efficient. The principle is the same as Berthelot's form; but whereas Berthelot's cover fits into the cylinder in the manner of a very wide stopper, the cover in this, as in Mahler's, rests directly upon the upper edge of the cylinder, a projection of the latter fitting into a groove in the former. A washer of lead is set in the groove of the cover, the latter is held tightly to the cylinder by a screw cap or collar and thus perfect closure is easily secured. The apparatus differs but slightly from that depicted in figure 1 herewith.

* *Compt. rend.*, 113, 774 and 862, and *Génie Civile*, Jan. 23, 1892, p. 198. See also *Zeitsch. f. anal. Chem.*, 1893, 79, and Berthelot, *Calorimétrie Chimique*, 133.

† Hempel, *Gasanalytische Methoden*, 1890, 355 and English translation, *Methods of Gas Analysis*, 1892, p. 359.

In Berthelot's bomb, as I am informed by the maker, it is found necessary to use a large amount of platinum in the stopper to make it firm, so that although the platinum lining of the cylinder below the neck is only about one-half millimeter thick, over a kilogram of platinum is required for the whole. This simple substitution of a platinum-lined steel cover saves the larger part of the platinum. The cost of the bomb in Dresden, with accessory apparatus, including vise-grip and lever for screwing on the collar, a cylinder for compressed oxygen, fittings, manometer and a screw press* for making hard pellets of the substance to be burned, was less than \$220. The apparatus has been in use in our laboratory for more than two years, all the combustions of which the results are given in the present Report were made with it, and we have found it very satisfactory.

The bomb as just described might be recommended for general use in place of the very expensive form devised by Berthelot. Our experience has, however, suggested some alterations, and the attempt is being made, to develop an apparatus which, without sacrifice of accuracy and reliability, will be durable, convenient and capable of being made at a cost which will bring it within the reach of ordinary laboratories. The efforts in this direction are being materially aided by the U. S. Department of Agriculture. The results thus far are very encouraging, but we are not yet certain what kind of metal will ultimately prove best for the bomb or for the lining, and there are numerous details of construction and manipulation which still need to be worked out and tested.

The main objective point at present is to diminish the cost of the lining. Whether this will be best accomplished by a cheaper lining of platinum, or by a lining of another metal, or by using a less corrosive metal than steel for the bomb and thus avoiding the lining altogether, remains to be seen. But there is no doubt as to the feasibility of making an excellent bomb of steel with a thin platinum lining.

Two steel bombs have been made by the Pratt & Whitney Co. of Hartford, Conn., and to whose personal interest in the matter, with that of Mr. G. M. Bond of their establishment, especial thanks are due. Their facilities for making such apparatus are very unusual in respect to mechanical appliances,

* As used by Hempel, loc. cit.

large experience, critical appreciation of the scientific demands, and means for insuring accuracy and finish of execution. Figure 1 herewith represents the last form of bomb adopted. It differs from the first one and from the one made in Germany as above described, chiefly in the introduction of the ball-bearings (K K).

A represents the cylinder, B the cover, and C the screw cap or collar by which the cover is held on the cylinder. The cover is provided with a neck (D). Into this fits, at the top, a cylindrical screw (E), into which in turn fits a valve screw (F). In the neck (D), where the bottom of the cylinder screw (E) rests, is a shoulder fitted with a washer of lead. On the side of D is an opening (G), into which may be screwed a tube connected with the receptacle which holds the oxygen used for the combustion. The tube when screwed in thrusts against a washer of lead at the end of G, which insures perfect closure. A narrow passage runs horizontally to the center of D, and then perpendicularly downwards through the cover, and thus provides passage for the oxygen to the interior of the bomb. This passage may be

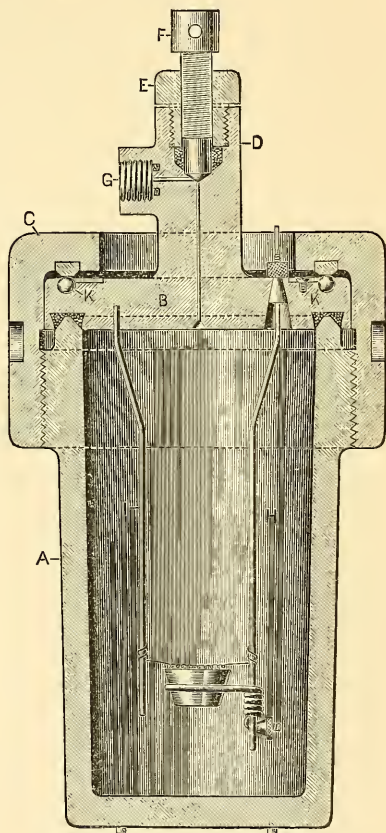


FIG. 1.—CALORIMETER BOMB.

tightly closed by the valve screw, the lower end of which is conical and thrusts against the inner surface of D, the angle of which at the place of contact corresponds to that of the tip of the screw. The upper edge of A is beveled on both sides, the apex being rounded, and fits into a washer of soft metal, which is held in a groove in the cover (B). Washers of lead have been used thus far. They yield to the heavy pressure and the metal gradually flows out of

the groove with use, so that the washers have to be replaced occasionally. With an instrument devised by Prof. Hempel a new washer can be cut out of a thick sheet of lead and inserted in a short time. We are, however, trying a washer of copper which will not flow so easily.

One difficulty in screwing the collar down tightly enough to prevent the escape of gas between the edge of the cylinder and the washer at the high pressure to which the gases are subjected, has been the friction of the collar upon the cover. To accomplish this the cylinder of the bomb is put in a clamp, which is fitted to the cylinder and is held in a vise. The collar is turned by a long-handled spanner, the projection of which fits into the two depressions shown in the collar. Even with a spanner handle nearly three-quarters of a meter in length, much force is needed to secure tight closure. To avoid the friction between the collar and the cover, ball-bearings (K K) of very hard steel, such as are employed for bicycles, are used in the last bomb made. These run in a groove in the cover and are kept from falling out by a flat ring which is easily removed. The bearing in the collar which comes against them, as shown in the picture, is also of hard steel.

The platinum wires, H and I, inside the bomb, serve to hold a platinum capsule containing the substance to be burned and to transmit an electric current. Of these two wires one, I, is screwed into the cover; the other, H, passes through a conical hole in the cover from which it is insulated by a piece of vulcanized rubber, in the shape of a frustum of a cone and fits the hole. A small nut screwed on the platinum wire at the upper surface of the cover draws the wire and with it the vulcanized rubber cone tightly into the hole and holds them in place. Near the lower end of H is a platinum wire bent in the form of a ring to hold the platinum capsule and coiled about the wire, to which it is held by a screw. When a combustion is made the two platinum wires are connected by a very fine iron wire which passes over the crucible. The part directly above the substance to be burned is bent into a spiral, thus furnishing a larger quantity of iron to be ignited and, falling, to ignite the substance in the crucible. The cylinder is approximately 12.5 centimeters deep and 6.2 in diameter inside. The wall is approximately .5 of a centimeter in thickness. The weight of the whole bomb is approximately 2,900 grams and its capacity nearly 380 cubic centimeters.

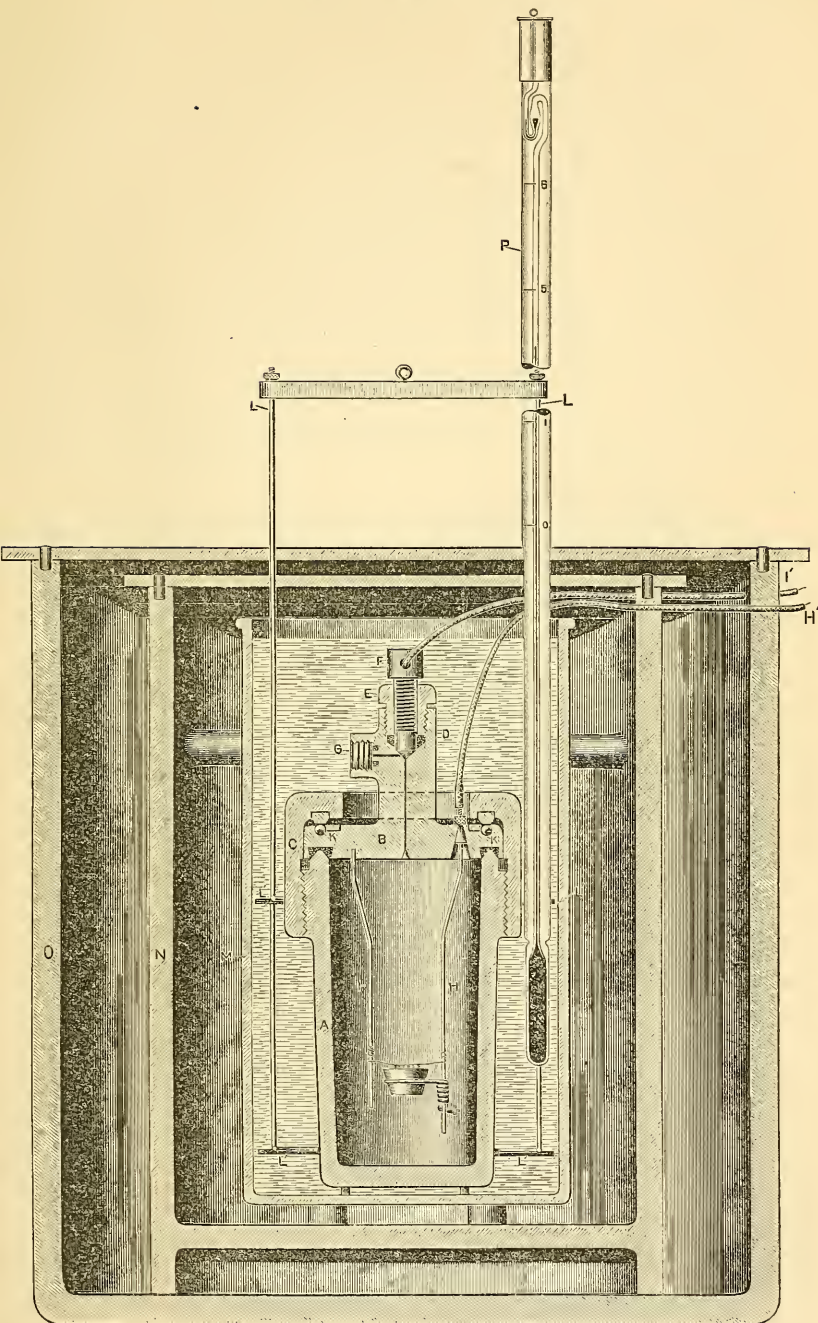


FIG. 2.—BOMB CALORIMETER; APPARATUS AS USED FOR ACTUAL DETERMINATIONS OF HEATS OF COMBUSTION.

The apparatus as set up for the combustion is shown in figure 2. M is the calorimeter cylinder. Those employed by Berthelot and Stohmann are made of brass. We have found the ordinary "white metal" used in making silver plated ware, which is essentially an alloy of tin, copper and antimony, well adapted to the purpose. This is large enough to hold the bomb and two liters of water, the water rising just to the top of the valve screw and very near to the top of the cylinder. L L is a stirrer which is moved up and down and thus brings the water to a uniform temperature. The calorimeter cylinder is contained in two larger concentric cylinders. In the apparatus as used by Berthelot and by Stohmann these are made of copper. They may be so joined that the space between the inner and outer one can be kept filled with

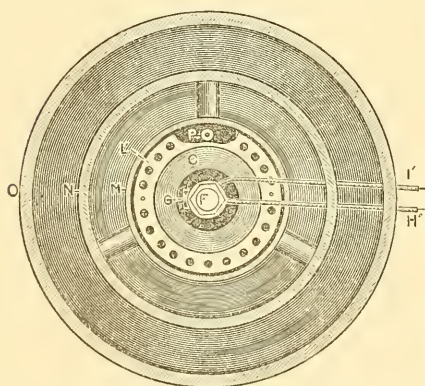


FIG. 3.—CROSS SECTION OF BOMB CALORIMETER APPARATUS.

water and thus effectually prevent the passage of heat from without inward. We have used cylinders of ordinary indurated fiber, N and O, with air spaces between. The indurated fiber is a good non-conductor of heat and we have found the arrangement satisfactory. Each of the two cylinders has a cover of vulcanized rubber. Beneath and on the sides of the calorimeter cylinder are supports of cork which keep it in place and prevent contact with cylinder N. The vulcanized rubber covers are each provided with two small holes through which pass the two upright rods of the stirrer and a larger hole for the thermometer P. In the sides of the two cylinders N and O near the top are holes through which pass wires H and I, to connect the platinum wires H and I with an electric battery. The whole apparatus is shown in cross section in figure 3. In this one of the flat, horizontal rings of the stirrer L is shown. This is wide enough to nearly fill the space between the bomb and the cylinder, but has a number of holes so that when it is moved up and down the water is not unduly agitated. One side is cut away to make room for the thermometer.

The cross bar at the top of the stirrer, shown in figure 2, has in the center a small ring. To this is attached a cord which connects with a wheel above. By the slow revolution of the latter the stirrer is raised and then allowed to fall by its own weight. The wheel is moved by a motor at nearly uniform rate so that the amount of motion of the stirrer in a given time is always nearly the same. The cross bar is held to the upright rods by nuts and is easily removed when the covers of N and O are taken off and put on.

The temperature of the water is measured by the thermometer P. We have several thermometers for this purpose. All are graduated to hundredths of a degree. One, which we employ as a standard thermometer for correcting the others and which is also very convenient for regular use, was made by Fuess and calibrated by the Physikalisch-technische Reichsanstalt in Berlin. The scale, which is 25 centimeters long, covers six degrees marked from 0 to 6. Each degree is divided into hundredths, and the divisions are of such length as to permit of easy estimates of thousandths by the aid of a magnifying glass. We are persuaded that, in this way, measurement of the temperature of the water to thousandths of a degree can be made with as close an approach to accuracy as the weighings to the tenths of a milligram with an ordinary laboratory balance. This especial thermometer is provided with a Boeckmann reservoir at the top into which a part of the mercury can be driven at will. The readings, therefore, as marked from 0 to 6 on the thermometer, may indicate actual temperatures from the freezing to the boiling point of water according as little or much mercury is driven into the reservoir. The thermometer is calibrated for measurements at any of these temperatures. The cost of the thermometer in Berlin was 37.50 marks, the charge for calibrating was 21 marks, making total cost in Berlin about \$17. We have found it very satisfactory.

The accessory apparatus consists of a screw press of the kind used by Hempel* for compressing the substance to be burned into a firm cylindrical cake, vise, vise-grip, lever for screwing the cap, a cylinder of compressed oxygen with tubes and manometer for filling the bomb, an electrical apparatus to furnish a current for igniting the substance (we connect directly with an electric lighting circuit, using a resistance coil to reduce the

* Gas Analysis, page 356.

current,) and the arrangement above referred to for moving the stirrer. The manipulation requires the same skill that is demanded for accurate laboratory determinations in general and no more. The actual process is briefly as follows: The substance to be burned is, when convenient, pressed into a cake, and, after weighing, put in the small platinum capsule; the latter is then placed in the ring support under the small iron wire connecting the two platinum wires H and I. The bomb cover, which holds these wires and with them the capsule, is then put on the cylinder, the collar is screwed on, the oxygen is introduced until the pressure indicates at least 20 atmospheres. The bomb is then put in the calorimeter cylinder inside the larger cylinders; the covers, stirrer, thermometer, and connecting wires H and I are properly arranged; and the apparatus is allowed to stand, generally for not more than three minutes, until the temperature of the water, which at the outset is two degrees or a little more below that of the room, begins to rise. Six initial readings are then taken at intervals of one minute, these generally show a rise of from two to four hundredths of a degree. At the moment of the sixth reading, which is taken for the initial temperature of water and apparatus, the current is turned on, the wire is ignited at the same moment and falls, igniting the substance. The combustion takes place quickly but quietly, and the temperature forthwith begins to rise. The thermometer is read for five minutes at intervals of one minute and again after ten minutes more. The first of the initial readings, the one at the moment of turning on the current, the five which follow and the last one are used in a formula* for computing the correction for the influence of the temperature of the air in the room upon the change in temperature of water and apparatus during the combustion. The result shows the actual rise of temperature of water and apparatus (bomb, calorimeter cylinder, stirrer and thermometer) due to the combustion. The next steps are to find the number of calories of heat which correspond to the rise of temperature of water and apparatus and then the calories of heat actually developed by the combustion of the substance. For the first it is necessary to know the thermal water equivalent of the apparatus. This has to be determined for each apparatus and under the circumstances in which it is to be used. The methods here followed are essentially those described by Stohmann, Kleber and Langbein.† The quantity of water thus

*The formula here used is essentially the same as developed by Stohmann, Kleber and Langbein, *Jour. f. prac. Chem.*, 147, 138, 517-523.

† Loc. cit. 524-536.

found to be thermally equivalent to the apparatus is added to the quantity of water actually used. The specific heat of this amount of water, compared with the rise in temperature as above determined, gives the actual number of calories of heat contributed to water and apparatus by the combustion. The total heat thus contributed includes the heat of combustion of the substance itself plus the heat of oxidation of the iron wire and the heat of formation of a certain amount of nitric acid, which is at the same time produced in small but varying quantity. To determine the heat of oxidation of the iron each wire is weighed at the outset. When, as is sometimes the case, a portion is left unoxidized, this is weighed at the end and the difference is taken as the amount oxidized. The purest piano wire is used and the heat produced is estimated from the amount oxidized and the otherwise observed heat of oxidation of iron (for Fe_3O_4 1,600 small calories per gram of Fe). The nitric acid which is dissolved in the water formed by the combustion in the bomb is rinsed out and the amount is determined by titration with a standard solution of sodium carbonate, one cubic centimeter of which will neutralize a quantity of nitric acid of which the heat of formation is one small calorie. Adding the heats due to the oxidation of the iron and the formation of nitric acid and subtracting the sum from the total heat communicated to the apparatus and water leaves the amount due to the oxidation of the substance.

There are, of course, numerous details of manipulation suggested by experience which hardly need be described here. One for instance is the use of a kindling material for animal and vegetable fats, in which the molten globule of iron oxide sometimes sinks until it is covered without igniting the substance. By laying a small portion, three to five milligrams, of naphthalene on top of the substance, ignition is made sure. Allowance is made for the heat of combustion of the naphthalene, which, for that we have used, is found to be 9,678 small calories per gram.

One essential feature is the oxygen. This we formerly obtained from Berlin, but it can now be had in New York, of satisfactory purity, in cylinders ready for use. With only a single cylinder, a force pump would be necessary to charge the bomb as soon as the pressure in the cylinder should fall below 20 atmospheres, which is the pressure required in the bomb. To avoid the necessity of a force pump we employ two cylinders with a device

by Stohmann, which consists of tubes and gas cocks so arranged that either cylinder can be connected with the bomb or disconnected without trouble. A manometer is joined to the tube leading to the bomb. One cylinder alone is used for charging until the pressure falls below 20 atmospheres. Thereafter, in charging, the oxygen is allowed to run from this cylinder into the bomb until the pressure is the same in both; the connection then is shut off and the other cylinder, in which the pressure is higher, is connected with the bomb and the charging up to 20 atmospheres is completed. In this way the oxygen in the first cylinder can be used until the pressure is reduced to one atmosphere. The cylinder is then sent away to be refilled. We find it convenient to have three cylinders and are thus never without at least one with sufficient pressure for charging.

The results of our experience thus far may be briefly summarized.

1. As to apparatus. The bombs we have had made at home as above described seem to promise better than anything we should be able to obtain from European makers. The strongest and best gun steel is to be had in this country and the workmanship is better than anything we have seen in apparatus of the kind made in France or Germany. We are not yet certain that the platinum lining can be more advantageously provided here than in Germany though that now seems probable. We are attempting to find a way to put on the lining by electroplating, using another metal between the steel and the platinum. If this proves successful it will materially lessen the cost; if it does not, a lining of sheet platinum can be used. We hope that it will prove feasible to use some cheaper metal than platinum for lining the steel bomb or to use some non-corrosive metal in the place of the steel for the whole bomb and thus avoid the lining entirely, but are not yet able to speak of the prospect of success. The accessory apparatus is simple and easily obtained.

There is therefore no doubt that an accurate, convenient, reasonably durable and inexpensive bomb calorimeter with the accessory apparatus can be made available to those who have occasion to use it.

2. As to method. To determine the thermal equivalent of the apparatus is a somewhat difficult and time-consuming operation, but when that is done and the schedules for noting the observations and the formulas for calculating the results are made out and the method of manipulation is well in hand, the

determinations of heats of combustion can be made quite rapidly and with a high degree of accuracy. Each determination of a heat of combustion involves: (1) either three or four weighings; one of the calorimeter cylinder and water to insure the right amount of the latter, one of the substance, one of the iron wire, and sometimes one of a small portion of the iron wire left unoxidized; (2) twelve observations of temperature of which eight are actually used; (3) one titration of nitric acid with standard alkali. The calculations for one determination can be made in the intervals of waiting between the observations of temperature of the next one. When the materials of which the heats of combustion are to be determined are ground and prepared for weighing in advance it is not difficult to make nine determinations and calculations in a working day of seven and one-half hours. The accuracy of the results is very satisfactory. Not only do duplicates agree with the greatest closeness, but we have made a considerable number of determinations with pure substances such as sugar, and have obtained results practically identical with those obtained by Berthelot and by Stohmann for the same substances. This identity of results obtained in the three laboratories is certainly very favorable for their correctness and for the reliability of the apparatus and method.

Table 45 gives the results of a considerable number of determinations of the heats of combustion of different foods and feeding stuffs made by the method and with the apparatus above described in the course of investigations here. Many of the combustions here reported were made by Dr. R. L. Slagle, whose skill and accuracy call for especial recognition. The special purpose in collating them is to compare the fuel values as obtained from calculation from the analysis and as determined by the bomb calorimeter. In calculating the potential energy each gram of protein is taken at 5.5 Calories, each gram of fat at 9.3 and each gram of carbohydrates at 4.1 Calories. The difference between the 5.5 Calories here used for one gram of protein and the factor 4.1* which we have ordinarily assumed is explained by the allowance made for the nitrogenous materials which are incompletely consumed in the body.

* See Report of this Station, 1890, pp. 177, 178.

TABLE 45.

Fuel Value Per Gram of Water-free Substance of Foods, Feeding Stuffs and Undigested Residues as Determined in the Bomb Calorimeter. (The Results of Analyses and the Calculated Fuel Values are also given for comparison.)

FOOD MATERIALS.	Laboratory Number.	Protein.	Fat.	CARBOHYDRATES.		Ash.	FUEL VALUE PER GRAM.	
				Fiber.	Nitrogen-free Extract.		As Calculated.	As Determined.
		%	%	%	%	%	Cal.	Cal.
ANIMAL FOODS.								
<i>Beef.</i>								
Porterhouse steak, - -	478	36.8	61.4	—	—	1.8	7735	7780
Porterhouse steak, - -	576	51.8	45.6	—	—	2.6	7085	7160
Porterhouse steak, - -	590	37.2	60.8	—	—	2.0	7705	7860
Average, - - - -	—	41.9	56.0	—	—	2.1	7510	7600
Sirloin steak, - - - -	488	47.4	50.1	—	—	2.5	7265	7355
Sirloin steak, - - - -	484	49.8	47.5	—	—	2.7	7155	7230
Average, - - - -	—	48.6	48.8	—	—	2.6	7210	7295
Shoulder steak, - - -	539	56.5	39.3	—	—	4.2	6760	6940
Shoulder steak, - - -	562	65.9	30.6	—	—	3.5	6475	6625
Shoulder steak, - - -	567	69.0	27.4	—	—	3.6	6340	6405
Shoulder steak, - - -	570	71.3	24.7	—	—	4.0	6225	6395
Average, - - - -	—	65.7	30.5	—	—	3.8	6450	6590
Round steak, - - - -	532	63.1	33.5	—	—	3.4	6585	6705
Round steak, - - - -	577	76.9	18.9	—	—	4.2	5985	6150
Round steak, - - - -	584	65.7	30.7	—	—	3.6	6470	6600
Average, - - - -	—	68.6	27.7	—	—	3.7	6345	6435
Rib roast, - - - -	489	33.4	64.9	—	—	1.7	7875	7925
Rib roast, - - - -	496	35.5	62.8	—	—	1.7	7790	7845
Rib roast, - - - -	540	63.5	33.5	—	—	3.0	6610	6740
Rib roast, - - - -	555	64.6	32.1	—	—	3.3	6540	6690
Rib roast, - - - -	566	63.5	32.8	—	—	3.7	6545	6720
Average, - - - -	—	52.1	45.2	—	—	2.7	7070	7185
Liver, - - - -	493	71.5	17.2	6.4	—	4.9	5795	5970
Canned corned beef, -	541	57.8	33.6	—	—	8.6	6305	6415
Dried smoked bologna, -	535	38.1	45.1	5.4	—	11.4	6510	6540
<i>Veal.</i>								
Leg, - - - -	483	60.8	35.9	—	—	3.3	6680	6580
Rib, - - - -	542	82.1	13.4	—	—	4.5	5765	5840
Rib, - - - -	565	75.5	20.5	—	—	4.0	6060	6180
Rib, - - - -	579	61.0	34.6	—	—	3.5	5445	6720
Average, - - - -	—	73.2	22.8	—	—	4.0	5425	6245
Loin, - - - -	578	88.5	6.3	—	—	5.2	5440	5565
<i>Mutton.</i>								
Chops, - - - -	485	37.6	60.3	—	—	2.1	7680	7780
Chops, - - - -	495	30.1	68.3	—	—	1.6	8005	8060
Average, - - - -	—	33.8	64.3	—	—	1.9	7845	7920
Leg, - - - -	490	36.6	61.3	—	—	2.1	7715	7740
Leg, - - - -	537	60.2	36.4	—	—	3.4	6605	6855
Average, - - - -	—	48.4	48.9	—	—	2.7	7205	7300

TABLE 45.—(Continued.)

FOOD MATERIALS.	Laboratory Number.	Protein.	Fat.	CARBOHY- DRATES.		Ash.	FUEL VALUE PER GRAM.	
				Fiber.	Nitrogen-free Extract.		As Calculated.	As Determined.
		%	%	%	%	%	Cal.	Cal.
<i>Pork.</i>								
Chops, - - - -	482	32.1	66.1	—	—	1.8	7915	8055
Chops, - - - -	486	29.3	69.1	—	—	1.6	8035	8140
Chops, - - - -	497	31.9	66.2	—	—	1.9	7910	7870
Average, - - - -	—	31.1	67.1	—	—	1.8	7955	8020
Bacon, - - - -	492	10.4	86.1	—	—	3.5	8575	8625
Smoked ham, - - - -	536	62.4	24.5	—	—	13.1	5715	5790
Smoked ham, - - - -	538	46.4	39.9	—	—	13.7	6260	6200
Smoked ham, - - - -	553	41.0	48.3	—	—	10.7	6745	6700
Smoked ham, - - - -	569	43.2	45.2	—	—	11.6	6575	6540
Average, - - - -	—	48.2	39.5	—	—	12.3	6325	6310
Salt pork, - - - -	531	4.6	91.7	—	—	3.7	8780	8885
Salt pork, - - - -	561	2.1	94.4	—	—	3.5	8895	8885
Average, - - - -	—	3.4	93.0	—	—	3.6	8840	8885
Turkey, right side, - - - -	487	37.4	60.9	—	—	1.7	7720	7670
Turkey, left side, - - - -	491	38.6	59.6	—	—	1.8	7665	7595
Average, - - - -	—	38.0	60.3	—	—	1.7	7695	7630
Fresh cod, - - - -	554	91.9	2.4	—	—	5.7	5280	5535
Oysters, - - - -	563	62.1	10.2	19.0	—	8.7	5145	5290
Cottolene, - - - -	552	—	100.0	—	—	—	9300	9560
Eggs, - - - -	494	42.1	54.1	—	—	3.8	7345	7065
Eggs, - - - -	568	54.8	41.6	—	—	3.6	6885	7015
Average, - - - -	—	48.4	47.9	—	—	3.7	7115	7040
<i>Dairy Products.</i>								
Cream cheese, - - - -	543	36.0	45.5	13.2	—	5.3	6750	6715
Butter, - - - -	4145	.8	95.1	—	—	4.1	8890	8870
Butter, - - - -	4150	.8	96.0	—	—	3.2	8965	9000
Butter, - - - -	4158	1.3	92.0	—	—	6.7	8630	8030
Average, - - - -	—	1.0	94.4	—	—	4.6	8830	8635
Milk, - - - -	4143	25.3	35.3	33.8	—	5.6	6060	6075
Milk, - - - -	4144	25.2	32.7	36.0	—	6.1	5905	6050
Milk, - - - -	4146	26.8	38.7	29.2	—	5.3	6205	6275
Milk, - - - -	4147	27.8	39.5	27.1	—	5.6	6310	6635
Milk, - - - -	4148	27.9	34.0	32.1	—	6.0	6010	6365
Milk, - - - -	4153	24.8	38.5	31.9	—	4.8	6255	6565
Milk, - - - -	4154	24.0	41.8	29.1	—	5.1	6400	6785
Milk, - - - -	4155	28.4	37.5	29.4	—	4.7	6258	8378
Milk, - - - -	4156	26.6	40.4	27.4	—	5.6	6341	6006
Milk, - - - -	4157	30.1	27.0	35.5	—	7.4	5627	5850
Average, - - - -	—	26.7	36.5	31.2	—	5.6	6135	6500
<i>VEGETABLE FOODS.</i>								
Potatoes, boiled, - - - -	558	10.7	.5	84.3	—	4.5	4095	4115
Potatoes, uncooked, - - - -	559	11.6	.7	83.8	—	3.9	4140	4155

TABLE 45.—(Continued.)

FOOD MATERIALS.	Laboratory Number.	Protein.	Fat.	CARBOHYDRATES.		Ash.	FUEL VALUE PER GRAM.	
				Fiber.	Nitrogen-free Extract.		As Calculated.	As Determined.
		%	%	%	%	%	Cal.	Cal.
Sweet potatoes, - - -	556	2.8	.9	93.8		2.5	4085	4040
Turnips, - - -	557	13.3	5.7	72.0		9.0	4210	4125
Squash, - - -	564	8.9	5.7	79.3		6.1	4270	4200
White beans, - - -	548	27.0	2.1	67.0		3.9	4430	4565
Macaroni, - - -	544	16.2	1.0	81.9		.9	4345	4565
Shredded cocoanut, - - -	546	6.7	66.6	25.2		1.5	7595	7340
Pearl tapioca, - - -	547	.3	.2	99.1		.4	4100	4170
Dates, - - -	587	2.8	6.5	88.8		1.9	4395	4050
Citron, - - -	588	.6	.8	97.4		1.2	4100	3965
Gelatine, - - -	589	94.5	.4	—		5.1	5235	5000
Bread, quaker, - - -	595	15.0	1.4	81.8		1.8	4310	4460
Bread, Saratoga, - - -	596	16.4	.6	80.9		2.1	4275	4405
Bread, home-made, - - -	597	14.7	.6	82.9		1.8	4265	4390
Bread, domestic, - - -	598	15.7	.9	81.4		2.0	4285	4415
Bread, cream, - - -	592	21.7	1.0	75.0		2.3	4365	4425
Bread, potato, - - -	600	15.6	.6	81.9		1.9	4270	4400
Bread, cornmeal, - - -	594	15.3	.6	82.1		2.0	4265	4475
Average, - - -	—	16.3	.8	80.9		2.0	4290	4425
<i>Milling Products.</i>								
Wheat flour, - - -	376	14.8	.9	83.7		.6	4330	4375
Wheat flour, - - -	378	13.7	.8	85.0		.5	4315	4340
Wheat flour, - - -	381	14.3	1.0	84.2		.5	4330	4355
Wheat flour, - - -	479	16.3	1.4	81.8		.5	4380	4345
Wheat flour, - - -	534	14.1	1.3	84.1		.5	4345	4400
Wheat flour, - - -	549	15.0	1.2	83.2		.6	4350	4440
Wheat flour, - - -	575	14.9	1.4	83.1		.6	4360	4380
Wheat flour, - - -	580	15.2	1.4	82.7		.7	4355	4705
Wheat flour, - - -	591	14.7	1.5	83.2		.6	4360	4425
Wheat flour, - - -	480	11.9	1.5	86.1		.5	4325	4345
Wheat flour, - - -	550	13.3	1.1	85.1		.5	4320	4510
Wheat flour, - - -	581	13.5	1.4	84.6		.5	4340	4715
Average, - - -	—	14.3	1.2	83.9		.6	4345	4445
Entire wheat flour, - - -	382	16.2	2.4	80.2		1.2	4400	4410
Rye flour, - - -	377	10.0	1.2	88.0		.8	4270	4290
Buckwheat flour, - - -	592	7.3	1.2	90.8		.7	4235	4325
Rolled oats, - - -	533	16.5	9.6	71.8		2.1	4740	4995
Rolled oats, - - -	551	19.5	7.7	70.8		2.0	4695	4905
Average, - - -	—	18.0	8.7	71.3		2.0	4720	4950
Quaker oats, - - -	582	16.0	8.0	74.1		1.9	4665	4910
Wheat germ meal, - - -	583	12.9	2.5	83.5		1.1	4365	4550
Corn meal, - - -	545	9.6	1.8	88.0		.6	4300	4405
Corn meal, - - -	1305	11.4	5.4	80.3	1.5	1.4	4485	4505
Corn meal, - - -	1300	11.6	4.9	80.6	1.5	1.4	4460	4520

TABLE 45.—(Continued.)

FOOD MATERIALS.	Laboratory Number.	Protein.	Fat.	CARBO- HYDRATES.		Ash.	FUEL VALUE PER GRAM.	
				Fiber.	Nitrogen-free Extract.		As Calculated.	As Determined.
		%	%	%	%	%	Cal.	Cal.
Corn meal, - - -	12699	9.7	4.0	82.4	2.6	1.3	4390	4400
Average, - - -	—	10.6	4.0	84.2	1.2	1.2	4410	4460
Oil meal, - - -	14870	39.2	2.3	10.0	42.7	5.8	4530	4635
Gluten meal, - - -	1207	13.1	15.4	63.8	6.3	1.4	5025	5590
Wheat bran, - - -	1208	20.5	5.9	60.5	7.4	5.7	4460	4645
Wheat bran, - - -	1301	18.9	5.9	58.0	11.2	6.0	4430	4585
Wheat bran, - - -	1304	19.9	5.6	57.1	11.1	6.3	4405	4585
Wheat bran, - - -	1306	18.4	5.7	59.2	10.3	6.4	4395	4555
Wheat bran, - - -	1338	18.1	5.6	58.3	11.3	6.7	4375	4530
Average, - - -	—	19.2	5.7	58.6	10.3	6.2	4415	4580
<i>Mixed Grain.</i>								
Linseed mixture,* - -	1302	33.6	6.2	48.7	6.7	4.8	4690	4735
Linseed mixture,* - -	1339	33.1	6.1	49.1	6.9	4.8	4685	4750
Average, - - -	—	33.4	6.1	48.9	6.8	4.8	4690	4745
Corn meal and cotton seed meal, - - -	11936	20.7	6.2	3.5	66.3	3.3	4575	4620
Cob meal, - - -	1209	9.6	5.4	81.6	1.8	1.6	4450	4545
<i>Seeds.</i>								
Oats and peas, ground, - -	1303	27.0	2.9	58.8	7.5	3.8	4470	4530
Oats and peas, ground, - -	1340	25.1	2.8	59.8	8.6	3.7	4445	4515
Average, - - -	—	26.1	2.9	59.3	8.0	3.7	4460	4525
Soy beans, - - -	1363	40.2	18.1	30.6	5.0	6.1	5355	5495
Soy beans, - - -	1364	40.0	18.1	31.0	5.4	5.5	5375	5510
Soy beans, - - -	1365	42.5	18.2	20.4	4.5	5.4	5420	5535
Average, - - -	—	40.9	18.1	30.3	5.0	5.7	5385	5515
<i>Hays.</i>								
Timothy, - - -	1006	9.1	3.8	46.9	33.0	7.2	4450	4810
Timothy, - - -	1007	10.4	3.6	48.1	31.1	6.8	4460	4850
Timothy, - - -	1355	11.6	3.2	43.4	36.2	5.6	4195	4595
Timothy, - - -	1356	6.8	2.7	52.5	31.7	6.3	4075	4515
Timothy, - - -	1357	19.5	3.2	33.7	37.9	5.7	4305	4530
Timothy, - - -	1358	7.8	3.6	45.7	37.4	5.5	4170	4545
Average, - - -	—	10.9	3.3	45.1	34.5	6.2	4275	4640
Rye grass, - - -	1008	12.6	2.9	48.7	27.7	8.1	4455	4745
Early cut hay, - - -	1325	12.0	4.0	44.2	34.1	5.7	4245	4515
Early cut hay, - - -	1326	12.5	3.9	45.4	32.7	5.5	4255	4505
Early cut hay, - - -	1327	12.1	3.9	42.9	35.3	5.8	4235	4520
Early cut hay, - - -	1328	12.2	3.8	44.9	33.3	5.8	4230	4505
Average, - - -	—	12.2	3.9	44.4	33.8	5.7	4240	4510
Scarlet clover, - - -	1341	19.6	5.0	39.4	25.5	10.5	4205	4370

* One part corn meal, 3 parts old process linseed meal.

TABLE 45.—(Continued.)

FOOD MATERIALS.	Laboratory Number.	Protein.	Fat.	CARBOHYDRATES.		Ash.	FUEL VALUE PER GRAM.	
				Fiber.	Nitrogen-free Extract.		As Calculated.	As Determined.
		%	%	%	%	%	Cal.	Cal.
Scarlet clover, - - -	1342	16.9	4.1	43.2	27.1	8.7	4190	4425
Scarlet clover, - - -	1343	18.7	4.7	39.6	27.0	10.0	4195	4355
Scarlet clover, - - -	1344	12.5	4.4	32.3	37.9	12.9	3975	4505
Scarlet clover, - - -	1345	12.5	5.2	33.1	36.0	13.2	4005	4610
Scarlet clover, - - -	1346	12.6	4.3	33.6	37.0	12.5	3990	4550
Scarlet clover, - - -	1418	16.4	2.1	36.7	36.3	8.5	4090	4375
Average, - - -	—	15.6	4.3	36.8	32.4	10.9	4095	4455
Tall meadow oat grass, -	1347	8.0	3.0	45.0	36.7	7.3	4070	4475
Tall meadow oat grass, -	1348	7.6	3.2	44.1	37.4	7.7	4055	4495
Tall meadow oat grass, -	1349	8.7	3.2	45.5	35.9	6.7	4115	4520
Tall meadow oat grass, -	1350	11.5	3.4	42.6	35.7	6.8	4155	4625
Average, - - -	—	9.0	3.2	44.3	36.4	7.1	4100	4530
Tall meadow fescue grass, -	1351	6.0	2.4	40.2	44.4	7.0	4020	4395
Tall meadow fescue grass, -	1352	6.0	2.4	50.3	34.1	7.2	4010	4110
Tall meadow fescue grass, -	1353	6.9	2.7	45.9	37.1	7.4	4035	4395
Tall meadow fescue grass, -	1354	9.6	3.1	39.7	39.1	8.5	4045	4655
Average, - - -	—	7.1	2.7	44.0	38.7	7.5	4030	4390
Orchard grass, - - -	1359	7.6	3.0	44.6	37.0	7.8	4045	4370
Orchard grass, - - -	1360	7.2	2.8	43.2	38.1	8.7	3995	4395
Orchard grass, - - -	1361	7.9	3.5	43.7	36.3	8.6	4045	4365
Orchard grass, - - -	1362	10.6	3.5	41.6	36.2	8.1	4095	4450
Average, - - -	—	8.3	3.2	43.3	36.9	8.3	4045	4395
Hay, - - -	8997	6.5	2.3	35.5	50.2	5.5	4085	4340
Hay, - - -	8795	8.1	2.1	35.6	48.0	6.2	4070	4420
Hay, - - -	12124	9.2	2.4	36.2	46.8	5.4	4130	4470
Hay, - - -	12568	7.7	2.2	36.7	48.8	4.6	4135	4440
Hay, - - -	14509	7.4	2.2	35.0	50.4	5.3	4115	4515
Average, - - -	—	7.8	2.2	35.8	48.9	5.3	4105	4435
Cow pea vines, - - -	1366	18.8	3.8	41.1	23.4	12.9	4035	4300
Cow pea vines, - - -	1367	17.8	4.3	44.5	20.9	12.5	4060	4265
Cow pea vines, - - -	1368	20.1	4.0	42.0	20.3	12.7	4070	4285
Average, - - -	—	18.9	4.0	42.9	21.5	12.7	4055	4285
Barley and pea fodder, -	1369	20.9	4.4	40.2	25.7	8.8	4265	4555
Barley and pea fodder, -	1371	19.1	4.0	41.2	26.3	9.4	4190	4520
Barley and pea fodder, -	1373	20.7	4.8	42.4	24.3	7.8	4320	4615
Barley and pea fodder, -	1375	19.4	3.5	43.4	26.0	7.7	4240	4720
Average, - - -	—	20.0	4.2	41.8	25.6	8.4	4255	4605
Barley fodder, - - -	1370	16.1	3.9	44.7	26.6	8.7	4175	4525
Barley fodder, - - -	1372	15.3	3.9	39.1	32.1	9.6	4120	4495
Barley fodder, - - -	1374	15.7	3.9	44.0	27.2	9.2	4145	4545
Barley fodder, - - -	1376	14.2	3.7	48.4	26.4	7.3	4190	4630
Average, - - -	—	15.3	3.9	44.0	28.1	8.7	4160	4550
Corn fodder, - - -	12125	7.9	2.1	27.7	56.2	6.1	4070	4325
Corn ensilage, - - -	1377	7.5	3.6	57.3	25.0	6.6	4115	4515
Rowen, - - -	1399	16.2	5.3	39.9	30.5	8.1	4270	4650
Rowen, - - -	1400	17.2	5.3	41.7	28.3	7.5	4310	4675
Average, - - -	—	16.7	5.3	40.8	29.4	7.8	4290	4665

TABLE 45.—(Continued.)

FOOD MATERIALS.	Laboratory Number.	Protein.	Fat.	CARBO- HYDRATES.		Ash.	FUEL VALUE PER GRAM.	
				Fiber.	Nitrogen-free Extract.		As Calculated.	As Determined.
<i>Feces.</i>	%	%	%	%	%	%	Cal.	Cal.
Man, - - - -	572	42.3	24.5	18.6		14.6	5365	6070
Man, - - - -	573	24.3	9.0	44.1		22.6	3980	6005
Man, - - - -	574	21.9	14.9	38.4		24.8	4165	6030
Man, - - - -	585	46.5	14.6	23.6		15.3	4880	5600
Average, - - - -	—	33.8	15.7	31.2		19.3	4600	5925
Sheep, - - - -	1307	16.6	4.6	26.4	42.5	9.9	4165	4700
Sheep, - - - -	1308	15.5	4.1	25.0	45.6	9.8	4125	4680
Sheep, - - - -	1309	16.2	4.5	26.4	41.3	11.6	4090	4665
Sheep, - - - -	1310	18.1	3.7	25.9	40.6	11.7	4065	4625
Sheep, - - - -	1311	15.8	4.2	25.7	42.7	11.6	4065	4585
Sheep, - - - -	1312	16.5	3.3	26.8	40.6	12.8	3980	4520
Sheep, - - - -	1313	18.5	5.0	25.7	40.9	9.9	4215	4780
Sheep, - - - -	1314	18.8	4.1	26.2	41.2	9.7	4180	4735
Sheep, - - - -	1383	12.0	3.7	39.4	32.7	12.2	3960	4650
Sheep, - - - -	1384	14.6	4.6	36.2	32.7	11.9	4060	4710
Sheep, - - - -	1385	10.8	4.5	35.8	38.9	10.0	4075	4730
Sheep, - - - -	1386	12.4	4.8	31.2	39.7	11.9	4035	4705
Sheep, - - - -	1395	15.0	7.6	28.0	39.4	10.0	4295	5040
Sheep, - - - -	1396	14.9	7.8	26.0	41.1	10.2	4300	5070
Sheep, - - - -	1397	14.0	7.8	26.3	42.8	9.1	4330	5070
Sheep, - - - -	1398	15.7	8.3	25.9	39.8	10.3	4330	5160
Sheep, - - - -	1401	14.9	7.1	28.9	38.2	10.9	4230	4995
Sheep, - - - -	1402	13.4	7.5	31.3	42.2	5.6	4445	4980
Sheep, - - - -	1403	14.1	7.3	28.7	39.6	10.3	4255	5010
Sheep, - - - -	1404	15.4	7.9	23.8	40.4	12.5	4215	5005
Sheep, - - - -	1419	11.1	2.2	46.1	31.4	9.2	3995	4565
Sheep, - - - -	1420	11.4	2.3	46.0	29.6	10.7	3940	4560
Sheep, - - - -	1421	11.2	2.4	42.5	34.1	9.8	3980	4535
Sheep, - - - -	1422	11.7	2.2	43.7	32.9	9.5	3990	4585
Sheep, - - - -	9292	8.0	2.6	41.0	40.6	7.8	4030	4630
Sheep, - - - -	9293	7.8	2.5	41.0	41.0	7.7	4025	4610
Sheep, - - - -	9294	7.3	2.3	43.2	40.3	6.9	4040	4615
Sheep, - - - -	10145	8.2	2.4	40.9	41.7	6.8	4065	4800
Sheep, - - - -	10146	8.6	2.4	41.3	40.1	7.6	4030	4705
Sheep, - - - -	10147	7.9	2.3	39.5	43.5	6.8	4050	4700
Sheep, - - - -	12803	7.6	2.2	49.5	34.7	6.0	4075	4765
Sheep, - - - -	12804	8.0	2.3	45.6	37.8	6.3	4075	4700
Sheep, - - - -	12126	13.8	2.4	33.8	40.1	9.9	4010	4615
Sheep, - - - -	12127	13.7	2.5	29.7	44.5	9.6	4030	4620
Sheep, - - - -	12128	12.7	2.1	41.3	34.7	9.2	4010	4565
Sheep, - - - -	12562	16.4	3.0	32.0	39.7	8.9	4120	4675
Sheep, - - - -	12563	17.9	2.4	24.2	45.8	9.7	4080	4580
Sheep, - - - -	12564	14.8	2.0	28.5	45.5	9.2	4035	4560
Sheep, - - - -	14958	8.8	1.7	45.9	36.8	6.8	4035	4725
Sheep, - - - -	14959	9.9	1.7	44.0	37.8	6.6	4055	4810
Sheep, - - - -	14960	9.6	1.5	41.8	40.5	6.6	4440	4655
Average, - - - -	—	12.9	3.9	34.4	39.4	9.4	4110	4730

METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.



The meteorological observations made at the Storrs Station during 1894 have been similar to those of past years. The Station equipment consists of the ordinary instruments for obtaining temperature, pressure of the air, humidity, rainfall and snowfall, uniform with those used by voluntary observers for the U. S. Weather Service. In addition to the records made at Storrs, the rainfall for the growing season has been recorded by farmers conducting field experiments for the Station, and a few other voluntary observers.

The total precipitation for the year (33.3 inches), as measured at the Station, was far below the average. The average annual precipitation for six Connecticut stations of the New England Meteorological Society, having records covering a period of ten or more years prior to 1890, is 49.1 inches. The average at Storrs for five years ending with 1893 is 46.8 inches, and including 1894 the average for six years is 44.5 inches. The monthly precipitation was least during the growing season (May–November). In many places the drouth became unusually severe during June and July, so that the hay and grain crops suffered considerably.

The temperature for January was a little above the average, while February was three degrees below the average, and March several degrees above. The spring opened later than usual. The last severe frost occurred May 15th, doing considerable damage to early vegetables. The summer was quite hot and dry with light rainfalls till September. Very light frost appeared on low ground September 12th, and the first killing frost occurred September 26th. This gave a growing season of 134 days since the last killing frost in the spring, while the average growing season since the Station began observations in 1888 is 143 days. The temperature for September and October was above the

average, and the conditions were favorable for harvesting most crops. Heavy snow came unusually early (November 6th), and many farmers had turnips and celery badly frosted.

Through the kindness of the New England Meteorological Society we are able to publish the rainfall records from sixteen of their Stations.

Table 46 gives the rainfall as recorded for the six months ending October 31st for twenty-three localities in the State, and table 47 gives the summary of observations made by the Station at Storrs.

TABLE 46.

Rainfall During the Six Months Ending October 31, 1894.

LOCALITY.	OBSERVER.	INCHES PER MONTH.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village, -	M. H. Dean, -	—	.86	1.35	.57	4.44	4.06	—
Norwalk, -	G. C. Comstock,* -	4.88	1.49	.83	1.23	5.52	5.86	19.81
Greenfield Hill, -	Sanford Jennings,* -	6.15	.87	.70	1.64	4.68	5.61	19.65
Bridgeport, -	William Jennings,* -	6.12	1.38	.69	2.29	5.86	7.25	23.59
Waterbury, -	N. J. Welton,* -	7.58	.54	2.43	2.41	5.35	4.91	23.22
New Hartford, -	R. R. Smith,* -	5.48	1.77	3.71	1.29	5.64	6.46	24.35
Canton, -	G. J. Case,* -	5.58	.58	1.92	.73	5.58	6.46	20.85
West Simsbury, -	S. T. Stockwell,* -	5.47	.59	1.95	.75	5.71	6.34	20.81
Southington, -	Lumen Andrews,* -	6.85	.65	2.00	2.15	5.60	6.30	23.55
New Haven, -	Weather Bureau,* -	4.49	.49	2.40	1.70	4.63	6.11	19.81
Wallingford, -	Mrs. B. F. Harrington,* -	4.56	.65	1.16	2.23	4.88	7.07	20.55
Hartford, -	Prof. S. Hart,* -	5.63	.31	1.44	2.44	5.82	6.50	22.14
South Manchester, -	K. B. Loomis, -	5.26	.66	1.70	2.84	2.37	5.42	18.25
Middletown, -	C. W. Hubbard,* -	5.29	.39	1.10	1.33	3.55	8.00	19.66
Madison, -	J. D. Kelsey, -	—	—	1.17	2.76	3.71	8.29	—
Lake Konomoc, -	New London W. W'ks,* -	3.91	.64	.93	1.35	2.09	6.77	15.69
New London, -	Weather Bureau,* -	3.53	.53	.44	2.91	2.59	7.21	17.21
Colchester, -	S. P. Willard,* -	4.03	.49	2.05	1.07	3.01	5.83	16.48
Lebanon, -	E. A. Hoxie, -	4.11	.66	2.06	1.73	2.48	5.96	17.00
Lebanon, -	J. H. Tucker, -	4.63	1.08	1.35	1.51	—	5.75	—
Storrs, -	Experiment Station, -	3.58	.59	2.09	2.37	3.01	4.16	15.80
Ekonk, -	George H. Gallup, -	—	.55	.41	2.15	2.63	—	—
Voluntown, -	Rev. C. Dewhurst,* -	4.25	1.42	1.83	2.22	2.30	5.64	17.66
Average, -	- - - - -	5.07	.75	1.55	1.81	4.15	6.18	19.79

* New England Meteorological Society Observer.

TABLE 47.
Meteorological Summary for 1894.
 OBSERVATIONS MADE AT STORRS BY THE STATION.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, -	30.74	30.84	30.50	30.48	30.42	30.30	30.27	30.19	30.54	30.41	30.65	30.49	30.44	—
Lowest barometer, -	28.92	29.23	29.57	29.66	29.58	29.58	29.72	29.81	29.71	29.20	29.42	29.39	29.48	—
Mean barometer, -	30.14	30.13	30.07	30.03	29.98	29.98	29.98	30.03	30.12	29.99	30.07	30.01	30.04	—
Highest temperature, -	54.8	47.0	64.5	74.0	85.0	90.0	95.0	83.8	86.0	22.5	63.7	52.0	72.3	—
Lowest temperature, -	2.0	-11.5	14.0	14.8	37.0	41.0	47.5	43.0	38.8	32.9	8.5	2.2	22.5	—
Mean temperature, -	27.7	23.0	38.6	44.7	56.4	66.0	70.9	65.8	63.0	50.6	34.1	28.2	47.4	—
Relative humidity, -	—	—	—	65.6	69.6	72.8	71.6	74.3	70.6	73.3	—	—	71.1	—
Total precipitation, -	2.24	3.13	1.18	2.67	3.58	.59	2.09	2.37	3.01	4.16	4.00	4.31	—	33.33
Number of days with precipitation of .01 inch or more,	12	11	9	8	8	7	10	5	9	9	11	9	—	108
Number of clear days, -	9	6	7	8	8	7	10	8	7	11	14	11	—	106
Number of fair days, -	11	12	15	9	10	10	17	15	15	10	7	11	—	142
Number of cloudy days, -	11	10	9	13	13	13	4	8	8	10	9	9	—	117

COÖPERATIVE FIELD EXPERIMENTS WITH
FERTILIZERS.

BY C. S. PHELPS.



The field experiments conducted by the Station at Storrs and in different parts of the State have been mainly "soil tests." Owing to the severe drouth which was so generally unfavorable to farm crops during July and August, most of these experiments were more or less injured. At best the deductions from any one experiment are mainly applicable only to the particular soil upon which the experiment was made and, to some extent, to similar soils in the immediate locality. When a large number of experiments, covering a great variety of soils in different localities are studied, some general deductions may be made. This has been done in Bulletin 10 and in the Fifth Annual Report, 1892, of this Station. The great number of soil test experiments there compiled show that heavy, clayey soils, in Connecticut, are generally lacking in phosphoric acid, while the lighter, more sandy soils show, in general, a lack of potash.

The object aimed at in these experiments has been to study the soils of different regions of the State and learn their deficiencies, and thus to help the owners to find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical manner. In many cases where experiments have been made we find farmers as well able to look after the details of the work as a representative of the Station. As the Station has taken up so many other lines of work it has been thought best not to continue "soil tests" as a regular branch of our work, but as far as individual farmers wish to test their own soil, to give instruction and advice.

The following persons and organizations have coöperated in this class of experiments during the past year:

										POST OFFICE.
J. M. Hull,	-	-	-	-	-	-	-	-	-	Madison.
J. D. Kelsey,	-	-	-	-	-	-	-	-	-	Madison.
E. K. Clauss,	-	-	-	-	-	-	-	-	-	Rockville.
Ekonk Grange,	-	-	-	-	-	-	-	-	-	Ekonk.
The Station,	-	-	-	-	-	-	-	-	-	Storrs.

We are glad to announce that one Grange in the State, which owns a small farm, has invited the Station to aid it in conducting a series of field experiments.

In connection with most of the experiments rainfall records have been kept during the growing season. These, with the records from quite a number of other localities in the State, will be found on page 159 of this Report. From these records it will be seen that during that part of the season (June, July and August) when the corn crop most needs moisture the rainfall was very deficient.

POUNDS REQUIRED FOR A BUSHEL OF DRY SHELLED CORN.

The percentages of water at harvest in the corn of the different experiments are found to vary considerably. The field weights are not an accurate measure of the value of the crop. The moisture and the proportions of cob to corn vary widely on different fields, but have been found to be fairly uniform on different plots of the same field. Moisture tests of the corn, at the time of harvest, have been made for all but one of the experiments in order to find the number of pounds of ears required to make a bushel of dry shelled corn. The differences in the percentages of water-free corn may be ascribed to two causes; variations in the proportion of corn to cob and variations in the moisture contained in the ears at harvest.

TABLE 48.

Percentages of Dry Matter of Corn in Ears (Grain and Cob) and the Number of Pounds of Ears Required for a Bushel of Shelled Corn.

NAME AND LOCALITY.	Water-free Corn in Samples (Ears) at Harvest.		Pounds of Ears at Harvest to Equal 56 lbs. Shel'd Corn with 11 % Water.	
	Good.	Poor.	Good.	Poor.
	%	%	Lbs.	Lbs.
J. M. Hull, Madison, - - -	68.4	61.1	73	81
J. D. Kelsey, Madison, - - -	61.6	55.3	81	90
E. K. Clauss, Rockville, - - -	70.0	62.7	71	79
Ekonk Grange, Ekonk, - - -	50.4	43.0	98	115
Station, Storrs, - - - -	59.5	56.8	84	87

The differences seen in the table point out the importance of knowing the moisture in the crop of each field instead of depending upon averages. From 70 to 75 pounds are commonly

considered a sufficient weight of ears to make one bushel of dry shelled corn. In these experiments an average of 81 pounds was required for the good corn.

SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consists in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station in standard commercial forms, such as nitrate of soda, dissolved bone-black, and muriate of potash. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus \$2 per ton for mixing and freight.

In most of the experiments a number of plots were added to the regular soil test. The object of these plots was to study the question of the most profitable mixture for use on particular soils.

On the following pages, the comparative yields of the experiments discussed are shown by means of diagrams. The fertilizers and the weights are given at the left of the diagram. The length of the lines represent the comparative yields per acre from the different plots, and the figures given in the last column show the actual yields per acre.

At the close of this article will be found a series of tabular statements, giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

EXPERIMENT BY E. K. CLAUSS.

The field upon which this experiment was located had been in grass for quite a period of years and was considerably "run down" by constant cropping without manures. One end of plots I and K extended onto ground that had been planted to potatoes the year before, and this may account in part for the small yields on those plots. The soil is a medium heavy loam with a gravelly clay subsoil. From the diagram it will be seen that the plots to which phosphoric acid (from dissolved bone-black) was applied, gave better yields than those where no phosphoric acid was used. This is in accord with many other experiments on similar soils.

SOIL TEST WITH FERTILIZERS ON CORN.

By E. K. CLAUSS, ROCKVILLE.

No. of Plot.	FERTILIZER.		YIELD SHELLLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o,	Nothing, - -	—		38.2
A,	Nitrate of Soda, -	160		37.6
B,	Dis. Bone-black, -	320		45.4
C,	Muriate of Potash,	160		41.6
D,	{ Nitrate of Soda, -	{ 160 }		47.1
	{ Dis. Bone-black, -	{ 320 }		
E,	{ Nitrate of Soda, -	{ 160 }		40.4
	{ Muriate of Potash, -	{ 160 }		
F,	{ Dis. Bone-black, -	{ 320 }		47.9
	{ Muriate of Potash, -	{ 160 }		
G,	{ Nitrate of Soda, -	{ 160 }		51.2
	{ Dis. Bone-black, -	{ 320 }		
oo,	{ Muriate of Potash, -	{ 160 }		42.8
	{ Nothing, - -	{ — }		
H,	{ Nitrate of Soda, -	{ 125 }		50.7
	{ Ammonite, -	{ 100 }		
	{ Muriate of Potash, -	{ 200 }		
	{ S. C. Dis. R'k Phos., -	{ 350 }		
I,	{ P. Cooper's Bone, -	{ 300 }		46.3
	{ Nitrate of Soda, -	{ 175 }		
K,	{ Muriate of Potash, -	{ 200 }		39.4
	{ Dry ground Fish, -	{ 510 }		

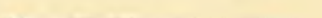
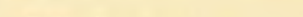
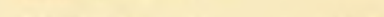
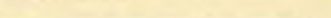
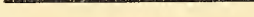
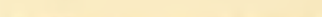
EXPERIMENT BY J. M. HULL.

The field where this experiment was located had been in grass the previous year, and, owing to a poor "catch," gave but a small yield. The field was sown to oats in 1892 and seeded to grass with the oats. When plowed in the spring of 1894, preparatory to the experiment, there was a thin turf of grass and clover. The soil is a light loam with a sandy to gravelly subsoil. The field sloped somewhat toward the first nothing plot (o) and the yield on that plot was no doubt considerably increased by the more favorable moisture conditions there found. For this reason it has been thought best to use only one nothing plot (oo) for calculating the gain on the other plots. Plot oo seemed to represent much more nearly the average condition of the soil. The results on plot H are omitted because of an error in planting. The soil on plots F and G was somewhat more gravelly

than on the other plots, and the crop there seemed to suffer more from the effects of the drouth. Nitrogen (from nitrate of soda) seemed to give the greatest increase of crop in this experiment, although all three of the fertilizing ingredients appeared to be somewhat lacking in the soil.

SOIL TEST WITH FERTILIZERS ON CORN.

By J. M. HULL, MADISON.

No. of Plot.	FERTILIZER.		YIELD SHELLLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O,	Nothing, - -	—		49.7
A,	Nitrate of Soda, -	160		52.4
B,	Dis. Bone-black, -	320		51.7
C,	Muriate of Potash, -	160		50.4
D,	{ Nitrate of Soda, -	160 }		61.1
	{ Dis. Bone-black, -	320 }		
E,	{ Nitrate of Soda, -	160 }		54.0
	{ Muriate of Potash, -	160 }		
F,	{ Dis. Bone-black, -	320 }		42.8
	{ Muriate of Potash, -	160 }		
G,	{ Nitrate of Soda, -	160 }		40.9
	{ Dis. Bone-black, -	320 }		
	{ Muriate of Potash, -	160 }		39.8
OO,	Nothing, - -	—		
H,	Nitrate of Soda, -	125		41.5
	Ammonite, - -	100		
	Muriate of Potash, -	200		
	S. C. Dis. R'k Phos., -	350		
I,	{ P. Cooper's Bone, -	300 }		52.4
	{ Nitrate of Soda, -	175 }		
	{ Muriate of Potash, -	200 }		
K,	{ Dry ground Fish, -	510 }		41.5
	{ Muriate of Potash, -	200 }		

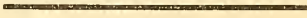
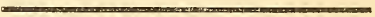
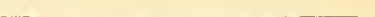
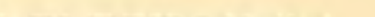
EXPERIMENT BY J. D. KELSEY.

The experiment by Mr. Kelsey was on a light loam soil with a sandy to gravelly subsoil. Rye was grown on the field in 1893, and at the same time the field was seeded to grass but failed to "catch." The soil of the field was quite uneven in texture and the drouth affected the plots unequally.

On the whole nitrogen gave the most striking results. Phosphoric acid and potash alone gave no increase over the nothing plot near by, although the nitrate of soda (A) plot gave an increase of 10.5 bushels over the nothing plot adjoining.

SOIL TEST WITH FERTILIZERS ON CORN.

By J. D. KELSEY, MADISON.

No. of Plot.	FERTILIZER.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o,	Nothing, - -	—		45.4
A,	Nitrate of Soda, -	160		55.9
B,	Dis. Bone-black, -	320		42.2
C,	Muriate of Potash, -	160		43.2
D,	{ Nitrate of Soda, -	160 }		55.2
	{ Dis. Bone-black, -	320 }		
E,	{ Nitrate of Soda, -	160 }		58.7
	{ Muriate of Potash, -	160 }		
F,	{ Dis. Bone-black, -	320 }		51.6
	{ Muriate of Potash, -	160 }		
G,	{ Nitrate of Soda, -	160 }		45.0
	{ Dis. Bone-black, -	320 }		
	{ Muriate of Potash, -	160 }		
oo,	Nothing, - -	—		41.6
H,	{ Nitrate of Soda, -	125 }		51.7
	{ Ammonite, -	100 }		
	{ Muriate of Potash, -	200 }		
	{ S. C. Dis. R'k Phos., -	350 }		
I,	{ P. Cooper's Bone, -	300 }		52.0
	{ Nitrate of Soda, -	175 }		
	{ Muriate of Potash, -	200 }		
K,	{ Dry ground Fish, -	510 }		55.4
	{ Muriate of Potash, -	200 }		

EXPERIMENT BY E KONK GRANGE.

In February, 1894, a representative of this Grange opened correspondence with the Station, stating that the Grange desired to undertake coöperative experiments running through a period of years. The committee from the Grange consisted of George H. Gallup and A. A. Stanton, of Ekonk, and John A. Tanner, of Campbell's Mills.

The soil of the field was a heavy clay loam with clay subsoil. The field had been in grass for a period of years without fertilizers and produced but small crops.

The experiment planned for 1894 was a soil test on corn with five additional plots designed to study the best and most economical mixture of fertilizer for the soil under the experiment, and similar soils in that vicinity. Plots I and K were supplied with uniform quantities of fertilizing ingredients, but on I the nitrogen

was added as nitrate of soda, and on K as organic nitrogen from animal flesh (ammonite). The yields in the two cases were essentially the same. Of the complete fertilizers, the most economical mixture was that used on plot M, costing \$13.00 per acre. The mixture supplied nitrogen and potash in the same proportion as the other complete fertilizers, but furnished phosphoric acid in quite large quantities (85 lbs. per acre). The results of the soil test part of the experiment, as far as showing the deficiencies of the soil is concerned, are not conclusive. A repetition of the work, under more favorable conditions of weather, is needed before conclusions can be drawn.

SOIL TEST WITH FERTILIZERS ON CORN.

By EKONK GRANGE, EKONK.

No. of Plot.	FERTILIZER.		YIELD SHELLD CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
O,	Nothing, - -	—		21.2
A,	Nitrate of Soda, -	160		22.4
B,	Dis. Bone-black, -	320		21.8
C,	Muriate of Potash, -	160		30.8
D,	{ Nitrate of Soda, - 160 }			27.3
	{ Dis. Bone-black, - 320 }			
E,	{ Nitrate of Soda, - 160 }			28.9
	{ Muriate of Potash, - 160 }			
F,	{ Dis. Bone-black, - 320 }			41.5
	{ Muriate of Potash, - 160 }			
G,	{ Nitrate of Soda, - 160 }			40.2
	{ Dis. Bone-black, - 320 }			
	{ Muriate of Potash, - 160 }			
OO,	Nothing, - -	—		23.4
H,	Ashes, - - -	1000		35.1
I,	{ Nitrate of Soda, - 160 }			43.8
	{ Muriate of Potash, - 160 }			
	{ Dis. Bone-black, - 480 }			
K,	{ Ammonite, - - 190 }			44.2
	{ Muriate of Potash, - 160 }			
	{ Dis. Bone-black, - 480 }			
L,	{ P. Cooper's Bone, - 500 }			41.1
	{ Nitrate of Soda, - 100 }			
	{ Muriate of Potash, - 160 }			
	{ Nitrate of Soda, - 90 }			
M,	{ Ammonite, - - 80 }			45.2
	{ Muriate of Potash, - 160 }			
	{ S. C. Dis. R'k Phos., - 600 }			
OOO	Nothing, - -	—		28.5

EXPERIMENT BY THE STATION.

This experiment is the fifth in a series planned as a rotation soil test experiment, the same fertilizers being used on the same plots year after year.* Beginning with 1890 the crops grown on this field have been corn, potatoes, oats, cow peas and corn.

The field slopes gently to the south, but not enough to cause serious washing. The soil is a heavy loam, and the subsoil is a yellow, clay loam. In 1889 it was noticed that the soil seemed to be poorer toward the west side of the field. For this reason the field was laid out into two half-acre experiments, the order of the plots on the two being reversed, as per diagram.

ARRANGEMENT OF PLOTS IN STATION EXPERIMENT.

UNMANURED STRIPS SEPARATE THE PLOTS.

EAST.

NORTH.	PLOT O.	SOUTH.	PLOT Y.
	PLOT A.		PLOT X.
	PLOT B.		PLOT OOO.
	PLOT C.		PLOT G.
	PLOT OO.		PLOT F.
	PLOT D.		PLOT E.
	PLOT E.		PLOT D.
	PLOT F.		PLOT OO.
	PLOT G.		PLOT C.
	PLOT OOO.		PLOT B.
	PLOT X.		PLOT A.
	PLOT Y.		PLOT O.

WEST.

The yields of the duplicate plots in each case are averaged in estimating the yield per acre. This helps to eliminate the errors due to irregularities of soil. Beside the regular soil test, two other plots were added—one (X) with a medium amount (12,000 pounds) of manure, and in addition dissolved bone-black at the rate of 160 pounds per acre; the other (Y) with a larger quantity (16,000 pounds) of stable manure, but without bone-black.

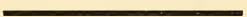
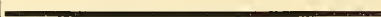
In 1890 a soil test with corn (the first of the series) was made upon these same plots with the following results, which are

* For description and results of earlier experiments on this field, see Report of this Station, 1890, pp. 69-71.

quoted from the Annual Report for 1891: "The results show that phosphoric acid had the most marked effect, nitrogen considerable, while potash gave but little increase over nothing. There is no very great increase from the use of any of the ingredients, and it seems probable that the soil was supplied with accumulated stores of fertility which the two years' cropping had not entirely exhausted."

SOIL TEST WITH FERTILIZERS ON CORN, 1894.

BY THE STATION, STORRS.

No. of Plot.	FERTILIZER.		YIELD SHELLED CORN PER ACRE. (11 % Water.)	
	Kind.	Lbs. per Acre.	Comparative Scale.	Bu.
o,	Nothing, - -	—		33.6
A,	Nitrate of Soda,	160		41.0
B,	Dis. Bone-black,	320		37.6
C,	Mur. of Potash,	160		40.8
oo,	Nothing, - -	—		28.0
D,	{ Nitrate of Soda,	160 }		40.8
	{ Dis. Bone-black,	320 }		
E,	{ Nitrate of Soda,	160 }		47.6
	{ Mur. of Potash,	160 }		
F,	{ Dis. Bone-black,	320 }		48.2
	{ Mur. of Potash,	160 }		
G,	{ Nitrate of Soda,	160 }		58.2
	{ Dis. Bone-black,	320 }		
	{ Mur. of Potash,	160 }		
ooo	Nothing, - -	—		38.9
X,	{ Stable Manure, -	12000 }		57.0
	{ Dis. Bone-black,	160 }		
Y,	Stable Manure, -	16000		56.7

The results for the past season show that all of the fertilizing ingredients were needed to produce good crops, but that potash was most essential, while in 1892, with oats, the nitrogen had the most marked influence. This illustrates the importance of modifying the fertilizer in accordance with the demand of the crop as well as the peculiarities of the soil.

Yields on Station Soil Test Experiment for past Five Years.

No. of Plot.	FERTILIZER.	Lbs. per Acre.	Corn. 1890.	Potato's 1891.	Oats. 1892.	Cow Peas (vines). 1893.	Corn. 1894.
	<i>Kind.</i>		Bu.	Bu.	Bu.	Lbs.	Bu.
o,	Nothing, - - -	—	28.9	89	29.1	10,230	33.6
A,	Nitrate of Soda, ' - -	160	32.4	105	36.0	10,960	41.0
B,	Dis. Bone-black, - - -	320	33.3	97	27.0	10,710	37.6
C,	Muriate of Potash, - - -	160	30.4	171	26.3	11,680	40.8
oo,	Nothing, - - -	—	26.7	87	24.2	9,725	28.0
D,	{ Nitrate of Soda, - - -	160 }	36.1	110	37.9	12,920	40.8
	{ Dis. Bone-black, - - -	320 }					
E,	{ Nitrate of Soda, - - -	160 }	32.8	160	30.0	13,335	47.6
	{ Muriate of Potash, - - -	160 }					
F,	{ Dis. Bone-black, - - -	320 }	34.4	214	27.8	15,790	48.2
	{ Muriate of Potash, - - -	160 }					
G,	{ Nitrate of Soda, - - -	160 }	37.4	259	39.4	16,210	58.2
	{ Dis. Bone-black, - - -	320 }					
	{ Muriate of Potash, - - -	160 }					
ooo,	Nothing, - - -	—	28.5	88	22.5	12,100	38.0
X,	{ Stable Manure, - - -	12000 }	44.1	210	40.9	15,795	57.0
	{ Dis. Bone-black, - - -	160 }					
Y,	Stable Manure, - - -	16000	43.6	250	41.3	15,875	56.7

The larger yields obtained last year (1894) on corn as compared with the season of 1890 are probably due to fertilizing materials left over from the leguminous crop (cow peas) grown in 1893. The beneficial effects of the growing of legumes, on soil fertility, and their importance in a rotation can not be too strongly urged on our farmers.

For general conclusion with the class of experiments the reader is referred to Bulletin 10 and the Fifth Annual Report of this Station.

Our thanks are due to Mr. Francisco J. San Roman, Honorary Delegate of the Chilian Nitrate Combination to the Columbian Exposition, for the nitrate of soda used in the experiments here reported upon.

TABLE 49.—SOIL TEST WITH FERTILIZERS ON CORN.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT 1-10 ACRE.			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.			Shel'd Corn (11% water).		Stover.	Gain over Nothing Plots.
				Good.	Poor.	Stover.	Good.	Poor.		
	<i>By E. K. Clauss, Rockville.</i>	Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O,	Nothing, - -	—	—	265	7	179	37.4	.8	1790	—
A,	Nitrate of Soda, -	160	3.96	267	—	156	37.6	—	1560	-2.9
B,	Dis. Bone-black, -	320	4.40	321	2	170	45.2	.2	1700	4.9
C,	Muriate of Potash, -	160	3.48	294	2	198	41.4	.2	1980	1.1
D,	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }		8.48	330	6	208	46.4	.7	2080	6.6
E,	{ Nitrate of Soda, - 160 } { Muriate of Potash, - 160 }		7.52	275	14	199	38.7	1.7	1990	-1.1
F,	{ Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }		8.00	327	14	198	46.2	1.7	1980	7.4
G,	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }		12.00	350	16	212	49.2	2.0	2120	11.7
oo,	{ Muriate of Potash, - 160 } Nothing, - -	—	—	289	17	183	40.7	2.1	1830	—
H,	{ Nitrate of Soda, - 125 } { Ammonite, - 100 } { Muriate of Potash, - 200 }		13.03	350	12	273	49.2	1.5	2730	10.2
I,	{ S.C. Dis. Rock Phos., - 350 } { Peter Cooper's Bone, - 300 }		12.98	317	14	233	44.6	1.7	2330	5.8
K,	{ Nitrate of Soda, - 175 } { Muriate of Potash, - 200 }		13.07	255	28	236	35.9	3.5	2360	-1.1
	<i>By J. M. Hull, Madison.</i>									
O,	Nothing, - -	—	—	349	16	231	47.8	1.9	2310	—
A,	Nitrate of Soda, -	160	3.96	367	18	271	50.2	2.2	2710	12.6
B,	Dis. Bone-black, -	320	4.40	364	16	265	49.8	1.9	2650	11.9
C,	Muriate of Potash, -	160	3.48	352	18	293	48.2	2.2	2930	10.6
D,	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }		8.48	433	15	319	59.3	1.8	3190	21.3
E,	{ Nitrate of Soda, - 160 } { Muriate of Potash, - 160 }		7.52	386	10	257	52.8	1.2	2570	14.2
F,	{ Dis. Bone-black, - 320 } { Muriate of Potash, - 160 }		8.00	306	8	211	41.9	.9	2110	3.0
G,	{ Nitrate of Soda, - 160 } { Dis. Bone-black, - 320 }		12.00	287	13	226	39.3	1.6	2260	1.1
oo,	{ Muriate of Potash, - 160 } Nothing, - -	—	—	278	15	214	38.0	1.8	2140	—
H,	{ Nitrate of Soda, - 125 } { Ammonite, - 100 } { Muriate of Potash, - 200 }		13.03	273	35	339	37.4	4.3	3390	—
I,	{ S.C. Dis. Rock Phos., - 350 } { Peter Cooper's Bone, - 300 }		12.98	374	10	183	51.2	1.2	1830	12.6
K,	{ Nitrate of Soda, - 175 } { Muriate of Potash, - 200 }		13.07	295	9	280	40.4	1.1	2800	1.7

TABLE 49.—(Continued.)
SOIL TEST WITH FERTILIZERS ON CORN.

No. of Plot.	FERTILIZERS PER ACRE.			YIELD PER PLOT. (1-10 Acre.)			YIELD PER ACRE.			
	Kind.	Weight.	Cost.	Ears.		Stover.	Shelled Corn (11 % Water.)		Stover.	Gain over Nothing Plots.
				Good.	Poor.		Good.	Poor.		
	<i>By J. D. Kelsey, Madison.</i>	Lbs.	\$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Bu.
O,	Nothing, - -	—	—	340	32	375	41.9	3.5	3750	—
A,	Nitrate of Soda, -	160	3.96	432	24	412	53.3	2.6	4120	12.4
B,	Dis. Bone-black, -	320	4.40	317	28	427	39.1	3.1	4270	-1.3
C,	Muriate of Potash, -	160	3.48	341	11	556	42.0	1.2	5560	-2.2
D,	{ Nitrate of Soda, -	160	8.48	435	14	423	53.7	1.5	4230	11.7
	{ Dis. Bone-black, -	320								
E,	{ Nitrate of Soda, -	160	7.52	464	14	453	57.2	1.5	4530	15.2
	{ Muriate of Potash, -	160								
F,	{ Dis. Bone-black, -	320	8.00	406	14	485	50.1	1.5	4850	8.1
	{ Muriate of Potash, -	160								
G,	{ Nitrate of Soda, -	160	12.00	350	17	496	43.2	1.8	4960	1.5
	{ Dis. Bone-black, -	320								
H,	{ Muriate of Potash, -	160								
	{ Nitrate of Soda, -	125								
H,	{ Ammonite, -	100	13.03	401	21	504	49.4	2.3	5040	8.2
	{ Muriate of Potash, -	200								
I,	{ S.C. Dis. Rock Phos., -	350								
	{ Peter Cooper's Bone, -	300								
I,	{ Nitrate of Soda, -	175	12.98	419	15	465	50.4	1.6	4650	6.5
	{ Muriate of Potash, -	200								
K,	{ Dry ground Fish, -	510	13.07	432	19	426	53.3	2.1	4260	11.9
	{ Muriate of Potash, -	200								
OO,	Nothing, - -	—	—	302	40	324	37.2	4.4	3240	—
	<i>By the Station.</i>									
O,	Nothing, - -	—	—	211	26	199	30.1	3.5	2388	—
A,	Nitrate of Soda, -	160	3.96	264	24	198	37.7	3.3	2376	7.5
B,	Dis. Bone-black, -	320	4.40	239	26	208	34.1	3.5	2496	4.1
C,	Muriate of Potash, -	160	3.48	260	27	259	37.1	3.7	3108	7.3
OO,	Nothing, - -	—	—	153	45	163	21.8	6.2	1956	—
D,	{ Nitrate of Soda, -	160	8.48	267	20	198	38.1	2.7	2376	7.3
	{ Dis. Bone-black, -	320								
E,	{ Nitrate of Soda, -	160	7.52	320	14	273	45.7	1.9	2276	14.1
	{ Muriate of Potash, -	160								
F,	{ Dis. Bone-black, -	320	8.00	322	16	326	46.0	2.2	3912	14.7
	{ Muriate of Potash, -	160								
G,	{ Nitrate of Soda, -	160	12.00	399	10	332	56.9	1.3	3984	24.7
	{ Dis. Bone-black, -	320								
OOO	{ Muriate of Potash, -	160								
	{ Nothing, - -	—								
X,	{ Stable Manure, -	12000	18.80	386	14	330	55.1	1.9	3960	23.5
	{ Dis. Bone-black, -	160								
Y,	Stable Manure, -	16000	19.20	378	20	338	54.0	2.7	4056	23.2

STUDIES OF DIETARIES.

REPORTED BY W. O. ATWATER AND CHAS. D. WOODS.



Accounts of studies of dietaries of families and a boarding house,*by the Station, have been given in previous reports, as follows:

- | | |
|---|---------------------------|
| 1. A boarding house.* | 5. A machinist's family.† |
| 2. A chemist's family.* | 6. A mason's family.† |
| 3. A jeweler's family.† | 7. A carpenter's family.† |
| 4. A blacksmith's family.† | 8. A carpenter's family.† |
| 9. The family of the Station Agriculturist in winter.‡ | |
| 10. A mason's family (the same as No. 6).‡ | |
| 11. A carpenter's family (the same as No. 8).‡ | |
| 12. A College students' club.‡ | |
| 13. The family of the Station Agriculturist in summer.‡ | |

Eight additional dietaries are here reported:

- | | |
|-----------------------------|--------------------------------------|
| 14. A widow's family. | 18. College lady students' club. |
| 15. A Swede family. | 19. A Swede family (same as No. 15). |
| 16. A College club. | 20. Three chemists. |
| 17. A Divinity School club. | 21. A carpenter's family. |

In the dietaries studies here reported upon the work was shared by Dr. H. B. Gibson, Mr. H. Monmouth Smith, Dr. R. L. Slagle, Dr. P. N. Evans, Mr. H. A. Torrey, Mr. H. M. Burr, Miss Katherine B. Camp and Miss H. M. Hall. The dietary study of a College club (No. 16) was under the especial charge of Dr. Gibson and Mr. Smith, that of a Divinity School club was largely the work of Mr. Smith. Miss Camp had the especial oversight of that of the College ladies' eating club (No. 18). The details of the study of the dietary of three chemists (No. 20) were carried out by Messrs. Smith, Slagle and Torrey.

The general plan of the investigation included an account of the amounts and composition of all food materials of nutritive value in the house at the beginning, purchased during and remaining at the end of the experiment, and of all the kitchen and table wastes. The amounts of different food materials on

* Report of this Station, 1891, pp. 90-106. † Report of this Station, 1892, pp. 135-162.
 ‡ Report of this Station, 1893, pp. 174-197.

hand at the beginning and received during the experiment were added; from this sum the amounts remaining at the end were subtracted. This gave the amount of each material actually used. From the amount thus obtained and the composition of each material, as shown by analysis, the amounts of the nutritive ingredients were estimated. From these were subtracted the amounts of nutrients in the waste, and thus the amounts of nutrients actually eaten were learned.

Account was kept of the meals taken by the different members of the family, and by visitors. The number of meals for one man, to which the total number actual meals taken was equivalent, was estimated upon the basis of the potential energy, as has been done in previous investigations here.* These energy equivalents, which are stated below, are somewhat arbitrary, and require revision in the light of accumulating inquiry. It has seemed best, however, to use the same figures here as in the previous reports and postpone the change until these dietaries may be summarized with others in a later publication.

*Estimated Relative Quantities of Potential Energy in Nutrients Required by
Persons of Different Classes.*

Man at moderate work,	-	-	-	-	-	-	10
Woman at moderate work,	-	-	-	-	-	-	8
Child, 15 months to 6 years old,	-	-	-	-	-	-	7
Child, 6 months to 2 years old,	-	-	-	-	-	-	5
Child, under 2 years old,	-	-	-	-	-	-	2½

EXPLANATION OF TABLES.

The figures in the first table of each dietary, giving the actual amounts of food and of nutrients in the food used during the dietary, are based upon the weights of the food materials as they were purchased and used; that is, they include bone and other refuse, except where specified.

The first three columns in the table contain the percentages of protein, fat and carbohydrates used in computing the amounts of those nutrients in the different food materials. In all cases where the composition was not fairly well known from previous analyses, specimens of the food materials actually used in the dietary, or specimens as nearly identical as possible, were analyzed. The cases in which special analyses were made in connection with these dietaries are indicated in the table by placing the letter *a* after the name of the material. The weights of the water-free

* See especially 17th Annual Report of the Massachusetts Bureau of Statistics of Labor, pp. 239-329.

table and kitchen wastes, and their composition, are given in the last line of the table. Exactly what is included in these wastes is explained in the foot note on page 97 of the Report of this Station for 1891.*

The last table in each dietary gives the nutrients and potential energy in food purchased, in table and kitchen wastes, and in the portion actually eaten. The estimates of animal and vegetable nutrients in the waste are computed as below described. In estimating the fuel values of the nutritive ingredients the protein and carbohydrates are assumed to contain 4.1 and the fats 9.3 calories of potential energy per gram.†

It was not practicable in the collection of the wastes to distinguish between that which came from animal and that from vegetable food. It is, however, possible to estimate with more or less accuracy how much of the nutritive materials came from the animal and how much from the vegetable foods. As there were practically no carbohydrates in any of the animal foods except milk and cheese, and but little in these, we shall not greatly err in assuming that all the waste carbohydrates came from the vegetable foods. It will also be fairly accurate to assume that there are the same proportions of protein, fat and carbohydrates in the vegetable waste as in the whole vegetable food purchased. In other words, the amount of vegetable protein and vegetable fat in the waste will bear nearly the same ratio to the total amount of vegetable protein and fat in the food purchased that the carbohydrates of the waste does to the total carbohydrates of the vegetable food. Taking the percentages of the weights of the carbohydrates in the total waste as the measure of the protein and fats in the vegetable wastes, the actual weights of protein and fat in the latter are readily calculated. Subtracting these weights of vegetable protein and fat from the total weight of these ingredients in the waste, the remainders give the amounts of animal protein and fats in the whole waste.

Table 66 summarizes the results of the twenty-one dietary studies which have been made by the Station.

* The words refuse and waste are used somewhat indiscriminately. In general, refuse in animal food represents inedible material, although bone, tendon, etc., which are classed as refuse, may be utilized for soup. The refuse of vegetable foods, such as parings, seeds, etc., represent not only inedible material, but also more or less of edible material. The waste includes the edible portion of the food, as pieces of meat, bread, etc., which might be saved, but is actually thrown away with the refuse.

† Report of this Station, 1890, p. 174.

No. 14.

DIETARY OF A WIDOW'S FAMILY.

The study began February 1, 1894, and continued 28 days. The members of the family and number of meals taken were as follows:

Woman, 45 to 50 years old, (assumed = .8 of one man,) $84 \times .8 = 67$ meals.

Girl, 16 years old, (assumed = .8 of one man,) $84 \times .8 = 67$ meals.

Boy, 19 years old, 84 meals.

Total equivalent to 218 meals, or 72 days for one man.

TABLE 50.

Food Materials and Table and Kitchen Wastes in Dietary of a Widow's Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbohy- drates.
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Beef.</i>							
Steak, cooked, - - -	26.7	17.1	—	310	83	53	—
Shoulder steak (a), - - -	16.8	16.5	—	1,445	243	238	—
Round steak, no bone (a), - - -	22.1	6.5	—	650	144	42	—
Shank, no bone, - - -	22.7	2.3	—	2,355	535	54	—
Flank, no bone, - - -	12.0	59.9	—	2,070	248	1,240	—
Total, - - -	—	—	—	6,830	1,253	1,627	—
<i>Pork.</i>							
Chops (a), - - -	15.1	14.5	—	1,840	278	268	—
Salt pork, - - -	.9	82.8	—	1,090	9	902	—
Lard, - - -	—	99.8	—	2,225	—	2,220	—
Total, - - -	—	—	—	5,155	287	3,390	—
<i>Fish, Etc.</i>							
Clams, without shell, - -	8.6	1.0	2.0	2,185	188	22	44
<i>Dairy Products, Etc.</i>							
Whole milk (a), - - -	3.3	4.1	4.2	8,860	292	363	372
Skimmed milk, - - -	2.4	.3	4.1	5,685	136	17	233
Butter, - - -	—	85.0	—	2,070	—	1,759	—
Cheese, - - -	28.3	35.5	1.8	850	241	302	15
Total, - - -	—	—	—	17,465	669	2,441	620
Eggs, - - -	14.9	10.5	—	1,050	156	110	—
Total animal food, -	—	—	—	32,685	2,553	7,590	664

TABLE 50.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
VEGETABLE FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
Cabbage (15.5 per cent. refuse),	1.5	.2	4.6	5,340	81	11	246
Onions (10 per cent. refuse), -	1.4	.3	10.1	2,260	32	7	228
Potatoes (15 per cent. refuse),	2.1	.1	17.9	28,890	607	29	5,170
Potatoes, cooked, - - -	2.6	.1	21.0	980	25	1	206
Split peas, - - - -	26.3	.9	61.4	570	150	5	350
Beans, dried, - - - -	23.1	2.0	59.2	1,830	423	37	108
Canned corn, - - - -	2.8	1.3	19.6	495	14	6	97
Rice, - - - - -	7.4	.4	79.4	340	25	1	270
Apples, etc., - - - -	.3	.4	15.9	2,480	7	9	394
Prunes, dried, - - - -	2.2	.5	66.6	455	10	2	303
Oranges, - - - - -	1.0	.9	8.3	705	7	6	59
Canned tomatoes, - - -	1.0	.2	3.7	540	5	1	20
Wheat bread, - - - -	9.1	1.6	56.0	1,120	102	18	627
Rye bread, - - - - -	8.4	.5	59.7	1,445	121	7	863
Cake, - - - - -	8.3	10.8	57.8	425	35	45	245
Milk crackers, - - - -	9.3	13.1	69.2	1,105	103	145	765
Pilot bread crackers, - -	12.4	4.4	74.2	455	56	20	335
Flour (a), - - - - -	16.4	1.3	81.7	24,650	4,042	320	20,139
Buckwheat flour, - - - -	6.9	1.4	76.1	470	32	6	358
Corn meal and samp, - - -	9.2	3.8	70.6	1,235	113	47	871
Oat meal, - - - - -	14.7	7.1	68.4	850	125	60	581
Extra C Sugar, - - - -	—	—	86.5	3,700	—	—	3,200
Molasses, - - - - -	—	—	72.0	1,790	—	—	1,238
Total vegetable food, - -	—	—	—	82,130	6,115	783	36,726
Total animal and vegetable food, - - - - - }	—	—	—	114,815	8,668	8,373	37,390
Table and kitchen wastes (a),	14.7	20.9	52.9	1,656	243	346	876

TABLE 51.

Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of a Widow's Family.

FOOD MATERIALS.		NUTRIENTS.			Fuel Value.
		Protein.	Fat.	Carbo- hydrates.	
<i>For Family, 28 Days.</i>		Grams.	Grams.	Grams.	Calories.
Food purchased, -	Animal, - -	2,553	7,590	664	83,775
	Vegetable, - -	6,115	783	36,726	182,915
	Total, - -	8,668	8,373	37,390	266,690
Waste, - - -	Animal, - -	100	328	—	3,460
	Vegetable, - -	143	18	876	4,345
	Total, - -	243	346	876	7,805
Foods actually eaten,	Animal, - -	2,453	7,262	664	80,315
	Vegetable, - -	5,972	765	35,850	178,570
	Total, - -	8,425	8,027	36,514	258,885
<i>Per Man Per Day.</i>					
Food purchased, -	Animal, - -	35	104	9	1,150
	Vegetable, - -	84	11	503	2,505
	Total, - -	119	115	512	3,655
Waste, - - -	Animal, - -	1	4	—	50
	Vegetable, - -	2	—	12	60
	Total, - -	3	4	12	110
Foods actually eaten,	Animal, - -	34	100	9	1,100
	Vegetable, - -	82	11	491	2,445
	Total, - -	116	111	500	3,545
<i>Percentages of Total Foods Purchased.</i>					
Food purchased, -	Animal, - -	29.5	90.6	1.8	31.4
	Vegetable, - -	70.5	9.4	98.2	68.6
	Total, - -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, - -	1.2	3.9	—	1.3
	Vegetable, - -	1.7	.2	2.3	1.6
	Total, - -	2.9	4.1	2.3	2.9
Foods actually eaten,	Animal, - -	28.3	86.7	1.8	30.1
	Vegetable, - -	68.8	9.2	95.9	67.0
	Total, - -	97.1	95.9	97.7	97.1

No. 15.

DIETARY OF A SWEDE FAMILY.

The study began February 2, 1894, and continued 28 days. The members of the family and number of meals taken were as follows:

Man, 28 years old, without steady employment, 84 meals.

Woman, 26 years old, (assumed = .8 of one man,) $84 \times .8 = 67$ meals.

Two girls, 3 and $5\frac{1}{2}$ years old, (each assumed = .4 of one man,) $2 \times 84 \times .4 = 67$ meals.

Child, 5 months old, (assumed = .25 of one man,) $84 \times .25 = 21$ meals.

Total equivalent to 239 meals, or 80 days for one man.

TABLE 52.

Food Materials and Table and Kitchen Wastes in Dietary of a Swede Family During Twenty-eight Days.

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Beef.</i>							
Sirloin, no bone (a), - -	19.6	16.1	—	1,115	219	179	—
Shoulder, no bone (a), - -	18.9	18.6	—	1,285	243	239	—
Shoulder, no bone (a), - -	17.3	16.4	—	1,410	244	231	—
Shoulder, no bone (a), - -	16.3	29.5	—	760	124	224	—
Round steak, no bone (a), -	21.9	6.4	—	975	380	39	—
Round steak, no bone (a), -	22.1	6.5	—	425	94	28	—
Shank, no bone (a), - -	23.3	5.4	—	1,160	270	63	—
Rump, no bone (a), - -	21.2	8.9	—	1,735	368	154	—
Corned beef, no bone (a), -	17.6	11.8	—	1,415	249	167	—
Corned beef, no bone (a), -	16.7	14.9	—	510	85	76	—
Canned corned beef, - -	26.7	17.1	—	735	196	126	—
Total, - - - -	—	—	—	11,525	2,472	1,526	—
Veal, no bone (a), - -	19.2	11.6	—	1,360	261	158	—
Frankfort sausage (a), - -	33.1	25.9	—	1,035	343	268	—
<i>Pork.</i>							
Chops, no bone (a), - -	8.1	15.3	—	845	68	129	—
Sparerib, no bone (a), - -	18.9	25.0	—	1,000	189	250	—
Chops, no bone (a), - -	19.7	19.0	—	525	103	100	—
Salt pork, - - - -	.9	82.8	—	1,460	13	1,205	—
Lard, - - - -	—	99.8	—	1,490	—	1,487	—
Total, - - - -	—	—	—	5,320	373	3,171	—
Pickled herring, - - -	20.2	8.8	—	1,190	240	105	—

TABLE 52.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.—(Con.) <i>Dairy Products.</i>	%	%	%	Grams.	Grams.	Grams.	Grams.
Skimmed milk, - - -	3.8	.4	3.5	28,265	1,074	113	989
Condensed milk, - - -	11.8	10.4	50.1	2,325	274	242	1,165
Butter, - - - - -	—	85.0	—	2,850	—	2,425	—
Total, - - - - -	—	—	—	33,440	1,348	2,780	2,154
Eggs, - - - - -	14.9	10.5	—	1,360	203	143	—
Total animal food, - -	—	—	—	55,230	5,240	8,151	2,154
VEGETABLE FOOD.							
Potatoes (15 per cent. refuse),	2.1	.1	17.9	1,660	35	2	297
Turnips (30 per cent. refuse),	1.2	.2	8.2	1,270	15	3	104
Onions (10 per cent. refuse), -	1.4	.3	10.1	500	7	1	50
Rice, - - - - -	7.4	.4	79.4	735	54	3	583
Dried beans, - - - - -	23.1	2.0	59.2	1,230	284	24	728
Canned peas (a), - - - - -	4.8	.3	11.3	1,015	49	3	115
Mince-meat preparation, -	4.0	2.2	67.4	695	28	15	468
Cranberries, - - - - -	.4	.9	10.9	495	2	4	54
Wheat flour (a), - - - - -	12.8	1.2	73.3	2,110	270	25	1,546
Wheat flour (a), - - - - -	13.9	1.4	73.8	17,805	2,475	249	13,140
Rye flour, - - - - -	6.7	.8	78.7	1,390	93	11	1,094
Oat meal (a), - - - - -	17.0	7.7	65.5	3,190	542	246	2,089
Corn meal (a), - - - - -	9.1	1.5	77.1	1,330	121	20	1,025
Cereline, - - - - -	11.9	1.7	74.6	185	22	3	138
Rye bread, - - - - -	8.4	.5	59.7	940	79	5	561
Milk crackers, - - - - -	9.3	13.1	69.2	3,600	335	472	2,491
Granulated sugar, - - - -	—	—	100.0	10,985	—	—	10,985
Molasses, - - - - -	—	—	72.0	1,700	—	—	1,224
Total vegetable food, - -	—	—	—	50,835	4,411	1,086	36,692
Total animal and vegetable food, - - - - - }	—	—	—	106,065	9,651	9,237	38,846
Table and kitchen waste (a), -	17.4	31.2	44.2	1,215	211	379	537

TABLE 53.

Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of a Swede Family.

FOOD MATERIALS.				NUTRIENTS.			Fuel Value.
				Protein.	Fat.	Carbo- hydrates.	
<i>For Family, 28 Days.</i>				Grams.	Grams.	Grams.	Calories.
Food purchased,	{	Animal,	- -	5,240	8,151	2,154	106,120
		Vegetable,	- -	4,411	1,086	36,692	174,500
		Total,	- -	9,651	9,237	38,846	280,620
Waste,	{	Animal,	- -	146	363	—	3,980
		Vegetable,	- -	65	16	537	2,610
		Total,	- -	211	379	537	6,590
Food actually eaten, -	{	Animal,	- -	5,094	7,788	2,154	102,140
		Vegetable,	- -	4,346	1,070	36,155	171,890
		Total,	- -	9,440	8,858	38,309	274,030
<i>Per Man Per Day.</i>							
Food purchased,	{	Animal,	- -	66	102	27	1,325
		Vegetable,	- -	55	14	446	2,285
		Total,	- -	121	116	473	3,610
Waste,	{	Animal,	- -	2	4	—	50
		Vegetable,	- -	1	—	7	30
		Total,	- -	3	4	7	80
Food actually eaten, -	{	Animal,	- -	64	98	27	1,275
		Vegetable,	- -	54	14	439	2,255
		Total,	- -	118	112	466	3,530
<i>Percentage of Total Foods Purchased.</i>							
Food purchased,	{	Animal,	- -	54.3	88.2	5.5	37.8
		Vegetable,	- -	45.7	11.8	94.5	62.2
		Total,	- -	100.0	100.0	100.0	100.0
Waste,	{	Animal,	- -	1.5	3.9	—	1.4
		Vegetable,	- -	.7	.2	1.4	.9
		Total,	- -	2.2	4.1	1.4	2.3
Food actually eaten, -	{	Animal,	- -	52.8	84.3	5.5	36.4
		Vegetable,	- -	45.0	11.6	93.1	61.3
		Total,	- -	97.8	95.9	98.6	97.7

No. 16.

DIETARY OF A COLLEGE CLUB.

The study began Feb. 7 and continued 28 days.

The club included 24 members, college students. There were in addition a colored waiter and two women (each assumed = .8 of one man). The number of meals taken were as follows: 24 students, 1,918 meals; colored waiter, 84 meals; two women, ($168 \times .8 =$) 134 meals; fed to tramps, 8 meals. Total equivalent to 2,144 meals, or 715 days for one man.

TABLE 54.

Food Materials and Table and Kitchen Wastes in Dietary of a College Club During Twenty-Eight Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbohy- drates.
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Beef.</i>							
Soup bones (a), - -	17.4	3.9	—	1,600	278	62	—
Sirloin steak (a), - -	19.2	10.7	—	15,425	2,962	1,650	—
Round steak (a), - -	18.4	12.3	—	9,750	1,794	1,199	—
Shoulder steak, - -	17.3	8.8	—	4,990	863	439	—
Rib roast (a), - -	14.3	13.6	—	5,130	734	698	—
Rib roast (a), - -	13.3	24.2	—	6,125	815	1,482	—
Rib roast, - -	13.8	18.9	—	12,475	1,722	2,358	—
Rump (a), - -	20.9	8.7	—	4,535	948	395	—
Rump (a), - -	21.2	9.8	—	3,005	637	294	—
Rump, - -	21.1	9.2	—	13,975	2,949	1,286	—
Corned beef (a), - -	16.9	11.3	—	4,595	777	519	—
Corned beef (a), - -	16.4	14.6	—	4,765	781	696	—
Corned beef, - -	16.7	13.9	—	13,295	2,220	1,848	—
Canned corned beef (a),	20.9	10.1	—	1,130	236	114	—
Dried and smoked, -	28.8	4.4	—	1,245	359	55	—
Liver, - - -	24.2	13.2	7.9	6,875	1,664	908	543
Total, - - -	—	—	—	108,915	19,739	14,003	543
<i>Veal.</i>							
Chops (a), - - -	16.2	3.9	—	3,175	514	124	—
Chops (a), - - -	16.7	5.4	—	3,290	549	178	—
Chops, - - -	16.5	4.6	—	10,545	1,740	485	—
Leg, no bone (a), - -	20.8	7.7	—	8,960	1,864	690	—
Miscellaneous cuts (a),	14.2	8.5	—	4,765	677	405	—
Miscellaneous cuts (a),	12.9	5.5	—	4,765	615	262	—
Miscellaneous cuts, -	13.5	7.0	—	10,350	1,397	725	—
Total, - - -	—	—	—	45,850	7,356	2,869	—

TABLE 54.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.—(Con.)	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Pork.</i>							
Chops (a), - - -	13.3	25.1	—	3,400	452	853	—
Chops (a), - - -	14.0	23.3	—	3,175	445	740	—
Chops, - - -	13.6	24.2	—	6,465	879	1,565	—
Spare rib (a), - - -	15.7	20.8	—	6,040	948	1,256	—
Spare rib (a), - - -	13.3	24.4	—	3,515	467	858	—
Spare rib, - - -	15.0	22.6	—	6,575	986	1,485	—
Bacon, - - -	11.8	62.5	—	9,695	1,144	6,060	—
Ham, - - -	14.8	34.6	—	11,370	1,683	3,934	—
Sausage (a), - - -	10.1	45.1	3.5	13,295	1,343	5,996	465
Salt pork, - - -	.9	82.8	—	5,385	48	4,459	—
Lard, - - -	—	99.8	—	3,655	—	3,648	—
Total, - - -	—	—	—	72,570	8,395	30,854	465
Cottolene, - - -	—	100.0	—	3,730	—	3,730	—
<i>Lamb.</i>							
Leg, - - -	15.0	15.6	—	12,500	1,875	1,950	—
<i>Fish, Etc.</i>							
Canned salmon (a), -	17.2	2.4	—	6,435	1,107	154	—
Dry salt cod, -	21.4	.4	—	3,530	755	14	—
Oysters, solids, -	6.3	1.6	4.0	5,445	343	87	218
Total, - - -	—	—	—	15,410	2,205	255	218
<i>Dairy Products.</i>							
Milk (a), - - -	3.6	4.5	4.1	323,605	11,650	14,562	13,268
Butter, - - -	—	85.0	—	42,735	—	36,325	—
Condensed milk, - -	11.8	10.4	50.1	1,020	124	106	511
Total, - - -	—	—	—	367,360	11,774	50,993	13,779
Eggs, - - -	14.9	10.5	—	16,910	2,520	1,776	—
Total animal food, -	—	—	—	643,245	53,864	106,430	15,005

TABLE 54.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
VEGETABLE FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
Pastry flour (a), - -	10.9	1.1	75.0	40,825	4,450	449	30,619
Bread flour (a), - -	14.2	1.2	70.3	49,440	7,020	593	34,756
Bread flour (a), - -	14.1	1.2	74.0	11,510	1,623	138	8,517
Graham flour (a), - -	17.7	3.6	66.0	16,585	2,936	597	10,946
Corn meal (a), - -	9.8	1.3	74.2	4,480	439	58	3,324
Rolled oats (a), - -	16.1	7.7	67.7	21,545	3,469	1,659	14,586
Cereline, - - -	9.4	1.0	78.6	4,165	392	42	3,274
Rice, - - -	7.4	.4	79.4	1,245	92	5	989
Hominy, - - -	8.3	.4	77.4	1,985	165	8	1,536
Oyster crackers, - -	11.3	4.8	77.5	5,570	629	267	4,317
Milk crackers, - -	9.3	13.1	69.2	21,945	2,041	2,875	15,186
Corn starch, - - -	—	—	97.8	1,160	—	—	1,134
Vermicelli, - - -	10.9	2.9	72.0	170	19	3	122
Cocoa and chocolate, -	6.8	21.0	67.6	805	55	169	544
Dessicated cocoanut, -	6.5	63.7	24.1	340	22	217	82
Molasses and maple syrup,	—	—	72.0	8,515	—	—	6,171
Granulated sugar, - -	—	—	100.0	73,410	—	—	73,410
Potatoes (28 % refuse), -	2.1	.1	17.9	19,613	412	20	3,511
Cabbage (15 % refuse), -	1.5	.2	4.6	13,762	206	28	633
Turnips (30 % refuse), -	1.2	.2	8.2	3,493	42	7	286
Carrots (15 % refuse), -	1.1	.4	8.9	842	9	3	75
Onions (10 % refuse), -	1.4	.3	10.1	981	14	3	99
Beans, dry, - - -	23.1	2.0	59.2	8,775	2,027	176	5,195
Apples (25 % refuse), -	.3	.4	15.9	15,405	46	62	2,449
Oranges (flesh), - -	1.0	.9	8.3	12,670	127	114	1,052
Prunes and raisins, - -	2.2	.5	66.6	1,160	26	6	773
Canned corn, - - -	2.8	1.3	19.6	1,035	29	13	203
Canned squash, - - -	.9	.5	11.8	5,670	51	28	669
Canned tomatoes, - -	1.0	.2	3.7	10,915	109	22	404
Canned peas, - - -	4.8	.3	11.3	4,365	210	13	493
Canned peaches, etc., -	1.1	.8	11.4	17,775	196	142	2,026
Cranberries, - - -	.4	.9	10.9	2,040	8	18	222
Mince meat ("none such"),	4.0	2.2	67.4	4,055	162	89	2,733
Total vegetable food, -	—	—	—	386,251	27,026	7,824	230,336
Total animal and vege- table food, - - - }	—	—	—	1,029,496	80,890	114,254	245,341
WASTE.							
Fat, - - -	—	100.0	—	10,135	—	10,135	—
Refuse (a), - - -	23.8	25.1	43.1	28,090	6,684	7,050	12,107
Total, - - -	—	—	—	38,225	6,684	17,185	12,107

TABLE 55.

Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of a College Club.

FOOD MATERIALS.		NUTRIENTS.			Fuel Value.
		Protein.	Fat.	Carbo- hydrates.	
<i>For Club, 28 Days.</i>		Grams.	Grams.	Grams.	Calories.
Food purchased,	Animal, -	53,864	106,430	15,005	1,272,200
	Vegetable, -	27,026	7,824	230,336	1,227,900
	Total, -	80,890	114,254	245,341	2,500,100
Waste, - - -	Animal, -	5,264	16,774	—	177,580
	Vegetable, -	1,420	411	12,107	59,280
	Total, -	6,684	17,185	12,107	236,860
Food actually eaten, -	Animal, -	48,600	89,656	15,005	1,094,620
	Vegetable, -	25,606	7,413	218,229	1,168,620
	Total, -	74,206	97,069	233,234	2,263,240
<i>Per Man Per Day.</i>					
Food purchased,	Animal, -	75	149	21	1,780
	Vegetable, -	38	11	322	1,720
	Total, -	113	160	343	3,500
Waste, - - -	Animal, -	7	23	—	245
	Vegetable, -	2	1	17	85
	Total, -	9	24	17	330
Food actually eaten, -	Animal, -	68	126	21	1,535
	Vegetable, -	36	10	305	1,635
	Total, -	104	136	326	3,170
<i>Percentages of Total Food Purchased.</i>					
Food purchased,	Animal, -	66.6	93.1	6.1	50.9
	Vegetable, -	33.4	6.9	93.9	49.1
	Total, -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, -	6.5	14.7	—	7.1
	Vegetable, -	1.8	.4	4.9	2.4
	Total, -	8.3	15.1	4.9	9.5
Food actually eaten, -	Animal, -	60.1	78.5	6.1	43.8
	Vegetable, -	31.6	6.4	89.0	46.7
	Total, -	91.7	84.9	95.1	90.5

DIETARY No. 17.

DIETARY OF STUDENTS IN A DIVINITY SCHOOL.

The following are results of dietary studies of a students' club in a divinity school in Connecticut. The most of the details were performed by Mr. H. Monmouth Smith, although Dr. H. B. Gibson shared in the work. The management of the club was in the hands of one of the members who acted as steward. The food was purchased under his direction. It was stored, cooked and eaten in rooms especially devoted to the use of the club.

Duration of Experiment.—The study was commenced on the afternoon of March 12, 1894, and continued for 10 days.

Members of the Club and Occupation.—The club consisted of 27 men, all of whom were studying for the ministry. The ages ranged from 22 to 38 years, and the average was $25\frac{1}{2}$ years. The weights of the members ranged from 130 to 180 pounds, the average being 149 pounds.

Of the members of this club 8 had their homes in Connecticut, 14 in other States, and 3 in Canada, while 2 were from foreign countries.

Seventeen were college graduates; 13 from colleges in the United States, 2 from Canada and 2 from foreign institutions. The members, like most men attending institutions of this character, were in quite moderate circumstances; one or two, however, were from decidedly well-to-do families. There were three women employed in the club, a cook, a waitress and a kitchen maid. The price of board in the club was nearly \$4.00 a week.

Meals Eaten.—An accurate account of all absences from the table was kept, as well as of all guests entertained. The record showed that 658 meals were served to the members and 90 to the servants. Assuming that a woman eats 0.8 as much as a man, the meals eaten by the women would equal 72 meals eaten by a man, and the total number of meals served would be 730, equivalent to three meals a day for one man for 243 days.

TABLE 56.
*Amounts and Composition of Food Materials and Amounts of
 Nutrients in Dietary of Divinity Students.*

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.				Fuel Value.
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.			
					Protein.	Fat.	Carbo- hydrates.	
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.	Calories.
<i>Beef.</i>								
Sirloin (a), - - -	15.5	25.9	—	3,345	519	866	—	—
Sirloin (a), - - -	16.9	16.1	—	6,350	1,073	1,022	—	—
Sirloin (a), - - -	15.6	16.5	—	2,948	460	487	—	—
Rib roast (a), - - -	13.5	26.2	—	8,080	1,091	2,117	—	—
Rib roast (a), - - -	14.1	25.0	—	4,508	636	1,127	—	—
Canned corn, - - -	26.7	17.1	—	2,948	787	504	—	—
Liver (a), - - -	21.5	5.2	2.0	1,021	207	53	20	—
Total, - - -	—	—	—	29,200	4,773	6,176	20	77,090
<i>Veal.</i>								
Leg (a), - - -	19.6	11.6	—	8,956	1,755	1,039	—	16,855
<i>Pork.</i>								
Chops (a), - - -	14.1	29.1	—	2,934	414	854	—	—
Chops (a), - - -	13.2	31.1	—	2,920	386	908	—	—
Chops (a), - - -	13.2	27.4	—	1,928	254	528	—	—
Fat, salt, - - -	.9	82.8	—	468	4	388	—	—
Bacon (a), - - -	7.7	64.0	—	1,021	79	653	—	—
Lard, - - -	—	99.8	—	3,515	—	3,508	—	—
Total, - - -	—	—	—	12,786	1,137	6,839	—	68,265
<i>Lamb.</i>								
Chops, - - -	13.9	26.6	—	1,247	174	331	—	—
Chops (a), - - -	14.8	23.7	—	2,920	432	693	—	—
Chops (a), - - -	13.0	29.5	—	1,814	236	535	—	—
Leg (a), - - -	15.1	25.3	—	6,010	908	1,521	—	—
Fore quarter, - - -	18.1	25.8	—	7,187	1,301	1,854	—	—
Total, - - -	—	—	—	19,178	3,051	4,934	—	58,395
Turkey (a), - - -	15.5	24.7	—	9,185	1,424	2,269	—	—
Turkey, - - -	15.5	24.7	—	7,683	1,191	1,898	—	—
Total, - - -	—	—	—	16,868	2,615	4,167	—	49,475
Gelatine, - - -	100.0	—	—	57	57	—	—	235
<i>Fish.</i>								
Salt cod, whole, -	16.0	.4	—	3,061	490	12	—	—
Shad, - - -	9.2	4.8	—	6,237	574	299	—	—
Oysters, solids, -	6.3	1.6	4.0	5,329	336	85	213	—
Mackerel, canned, -	29.9	19.9	8.7	369	110	73	32	—
Sardines, canned, -	43.6	25.3	12.7	1,814	791	459	230	—
Total, - - -	—	—	—	16,810	2,301	928	475	20,010

TABLE 56.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.				Fuel Value.
	Protein.	Fat.	Carbo- hydraes.	Total Food Materials.	Nutrients.			
					Protein.	Fat.	Carbo- hydrates.	
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.	Calories
<i>Dairy Products.</i>								
Milk (a), - - -	3.6	4.2	4.2	172,364	6,205	7,239	7,239	—
Butter (a), - - -	1.5	80.4	—	11,056	166	8,889	—	—
Cheese, - - -	28.0	35.3	2.1	1,687	473	596	36	—
Total, - - -	—	—	—	185,107	6,844	16,724	7,275	213,420
Eggs, - - -	10.2	13.1	—	22,126	2,256	2,899	—	36,210
Total animal food, -	—	—	—	311,088	24,789	43,706	7,770	539,955
<i>VEGETABLE FOOD.</i>								
Potatoes, 36.5 % waste,	2.1	.1	17.9	51,215	1,076	51	9,167	42,470
Potatoes, sweet, 15 % waste, - - -	1.5	.4	26.0	4,193	63	17	1,090	4,885
Beets, 15 % waste, -	1.5	.1	8.8	3,856	58	39	339	1,990
Parsnips, 15 % waste, -	1.3	.7	16.2	3,157	41	22	511	2,470
Turnips, 30 % waste, -	1.2	.2	8.2	715	9	1	59	290
Carrots, 15 % waste, -	1.1	.4	8.9	145	2	1	12	65
Lima beans, - - -	7.1	.7	22.0	3,770	264	26	829	4,725
Canned corn, - - -	3.0	1.3	22.5	2,509	75	34	565	2,940
Canned squash, - -	1.1	.5	9.9	5,232	58	3	518	2,390
Canned tomatoes, -	1.0	.2	3.3	2,183	22	4	72	420
Apples, 25 % waste, -	.3	.4	15.9	10,985	33	44	1,747	7,705
Apples, evaporated, -	1.3	.8	68.3	751	10	6	513	2,200
Raisins, - - -	2.7	.7	71.6	142	4	1	102	445
Currants, - - -	2.7	.7	71.6	42	1	—	30	125
Bread flour (a), - -	14.6	1.3	73.1	35,039	5,115	455	25,613	130,215
Pastry flour (a), - -	10.4	1.3	75.3	3,856	400	50	2,904	14,010
Graham flour, - - -	11.7	1.7	71.7	5,415	634	92	3,883	19,375
Rolled oats, - - -	13.4	6.7	70.2	4,082	546	273	2,865	16,525
Corn meal, - - -	9.2	3.8	70.6	1,545	142	59	1,090	5,600
Pearl barley, - - -	8.4	.7	78.1	482	41	3	376	1,740
Pearl hominy, - - -	8.3	.4	77.4	1,389	115	6	1,073	4,925
Rice, - - -	7.4	.4	79.4	312	23	1	248	1,120
Tapioca, - - -	—	—	97.8	113	—	—	111	455
Starch, - - -	—	—	97.8	794	—	—	776	3,180
Macaroni, - - -	13.3	.3	75.4	765	102	2	577	2,805
Sugar, - - -	—	—	100.0	20,653	—	—	20,653	84,675
Molasses, - - -	—	—	72.0	340	—	—	245	1,005
Syrup, - - -	—	—	67.0	2,423	—	—	1,623	6,655
Syrup, maple, - - -	—	—	50.0	1,361	—	—	681	2,790
Mince meat, - - -	4.0	2.2	67.4	737	30	16	497	2,310
Total vegetable food,	—	—	—	168,201	8,864	1,206	78,769	370,505
Total animal & vegeta- ble food purchased,	—	—	—	479,289	33,653	44,912	86,539	910,460
Table & k'ch'n waste(a),	20.9	24.1	48.8	19,257	4,024	4,651	9,398	98,280
Fat, - - -	—	1.00	—	6,660	—	6,660	—	61,940
Total, - - -	—	—	—	25,917	4,024	11,311	9,398	160,220

TABLE 57.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of Divinity Students.

FOOD MATERIALS.				NUTRIENTS.			Fuel Value.
				Protein.	Fat.	Carbo- hydrates.	
<i>For Club, 10 Days.</i>				Grams.	Grams.	Grams.	Calories.
Food purchased, -	{	Animal, - -	-	24,789	43,706	7,770	539,955
		Vegetable, - -	-	8,864	1,206	78,769	370,505
		Total, - -	-	33,653	44,912	86,539	910,460
Waste, - - -	{	Animal, - -	-	2,967	11,167	—	116,015
		Vegetable, - -	-	1,057	144	9,398	44,205
		Total, - -	-	4,024	11,311	9,398	160,220
Food actually eaten, -	{	Animal, - -	-	21,822	32,539	7,770	423,940
		Vegetable, - -	-	7,807	1,062	69,371	326,305
		Total, - -	-	29,629	33,601	77,141	750,245
<i>Per Man Per Day.</i>							
Food purchased, -	{	Animal, - -	-	102.0	179.9	32.0	2,220
		Vegetable, - -	-	36.5	4.9	324.1	1,525
		Total, - -	-	138.5	184.8	356.1	3,745
Waste, - - -	{	Animal, - -	-	12.1	46.0	—	480
		Vegetable, - -	-	4.4	.5	38.7	180
		Total, - -	-	16.6	46.5	38.7	660
Food actually eaten, -	{	Animal, - -	-	89.8	133.9	32.0	1,740
		Vegetable, - -	-	32.1	4.4	285.4	1,345
		Total, - -	-	121.9	138.3	317.4	3,085
<i>Percentages of Total Food Purchased.</i>							
Food purchased, -	{	Animal, - -	-	73.7	97.3	8.9	59.3
		Vegetable, - -	-	26.3	2.7	91.1	40.7
		Total, - -	-	100.0	100.0	100.0	100.0
Waste, - - -	{	Animal, - -	-	8.8	24.9	—	12.8
		Vegetable, - -	-	3.1	.3	10.9	4.8
		Total, - -	-	11.9	25.2	10.9	17.6
Food actually eaten, -	{	Animal, - -	-	64.9	72.5	8.9	46.5
		Vegetable, - -	-	23.2	2.3	80.2	35.9
		Total, - -	-	88.1	74.8	89.1	82.4

No. 18.

DIETARY OF A COLLEGE LADIES' EATING CLUB.

The study began April 13, 1894, and continued 10 days. The club included 34 members, lady students and four female servants, all over 18 years of age with one exception. 1,538 meals were taken; these were equivalent to 513 days for one woman or (assuming a woman = .8 of one man) 410 days for one man.

TABLE 58.

Food Materials and Table and Kitchen Wastes in Dietary of a Ladies' College Eating Club for Ten Days.

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Beef.</i>							
Rib roast (a), - - -	12.5	27.9	—	13,675	1,709	3,815	—
Rib roast (a), - - -	12.7	31.3	—	13,795	1,752	4,318	—
Rib roast (a), - - -	15.6	34.3	—	14,615	2,280	5,013	—
Rib roast (a), - - -	13.5	25.8	—	10,630	1,435	2,743	—
Sirloin steak (a), - - -	15.2	20.4	—	6,745	1,025	1,376	—
Sirloin steak (a), - - -	16.1	23.6	—	5,670	913	1,338	—
Sirloin steak (a), - - -	15.9	30.4	—	5,385	856	1,637	—
Sirloin steak (a), - - -	17.6	15.6	—	6,065	1,067	946	—
Shin, - - - - -	13.6	1.4	—	5,345	727	75	—
Liver, - - - - -	20.1	5.4	3.5	1,160	233	63	41
Corned (a), - - -	13.9	28.5	—	14,910	2,072	4,249	—
Total, - - - - -	—	—	—	97,995	14,069	25,573	41
<i>Veal.</i>							
Cutlet, - - - - -	21.1	10.6	—	3,090	652	328	—
Shank, - - - - -	10.0	5.3	—	1,220	122	65	—
Loin (a), - - - - -	14.0	13.7	—	8,815	1,234	1,208	—
Total, - - - - -	—	—	—	13,125	2,008	1,601	—
<i>Pork.</i>							
Ham, - - - - -	14.8	34.6	—	4,250	629	1,471	—
Salt pork, - - - - -	.9	82.8	—	1,220	11	1,010	—
Total, - - - - -	—	—	—	5,470	640	2,481	—

TABLE 58.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.—(Con.)	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Mutton.</i>							
Leg (a), - - -	15.8	16.1	—	7,770	1,228	1,251	—
Leg (a), - - -	14.6	18.4	—	6,110	892	1,124	—
Leg, - - -	15.2	17.3	—	9,525	1,448	1,648	—
Chops (a), - - -	12.4	36.3	—	6,265	777	2,274	—
Chops (a), - - -	12.3	38.2	—	4,605	566	1,759	—
Chops, - - -	12.4	37.3	—	5,020	622	1,872	—
Flank, - - -	15.4	44.1	—	2,240	345	988	—
Total, - - -	—	—	—	41,535	5,878	10,916	—
<i>Poultry.</i>							
Turkey, - - -	23.9	8.7	—	34,885	8,338	3,035	—
<i>Fish, Etc.</i>							
Shad, - - -	9.2	4.8	—	2,380	219	114	—
Clams, - - -	8.6	1.0	2.0	1,930	166	19	39
Oysters, - - -	6.3	1.6	4.0	2,495	157	40	100
Salt cod, - - -	21.4	.4	—	2,635	564	11	—
Canned salmon, - - -	20.1	15.7	—	1,560	314	245	—
Total, - - -	—	—	—	11,000	1,420	429	139
Cottolene, - - -	—	100.0	—	10,090	—	10,090	—
Gelatine, - - -	82.2	.4	—	510	419	2	—
<i>Dairy Products.</i>							
Milk (a), - - -	3.9	4.8	4.2	13,665	533	656	574
Butter (a), - - -	.9	86.1	—	20,215	182	17,405	—
Cheese, - - -	28.3	35.5	1.8	225	64	80	4
Total, - - -	—	—	—	34,105	779	18,141	578
Eggs, - - -	12.1	10.2	—	25,770	3,118	2,629	—
Total animal food, -	—	—	—	274,485	36,669	74,897	758
<i>VEGETABLE FOOD.</i>							
Potatoes (no refuse), -	2.1	.1	17.9	79,655	1,673	80	14,258
Carrots (15 % refuse), -	1.1	.4	8.9	1,400	15	6	225
Parsnips (20 % refuse), -	2.0	.4	15.5	11,705	234	47	1,814
Turnips (30 % refuse), -	1.2	.2	8.2	4,765	57	10	391

TABLE 58.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHT USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
	%	%	%	Grams.	Grams.	Grams.	Grams.
VEGETABLE FOOD.— <i>Con.</i>							
Spinach, - - -	2.1	.5	3.1	9,100	191	46	282
Cranberries, - - -	.4	.9	10.9	1,815	7	16	198
Onions (10 % refuse), -	1.4	.3	10.1	410	6	1	41
Cabbage (15 % refuse), -	1.5	.2	4.6	5,395	81	11	248
Oranges, - - -	1.0	.9	8.3	5,800	58	52	481
Canned peas, - - -	4.3	.3	11.4	2,380	102	7	270
Canned green beans, -	4.0	.5	13.5	4,765	191	24	643
Canned peaches, etc., -	1.1	.8	11.4	22,480	247	180	2,563
Canned corn (<i>a</i>), - - -	2.1	.8	13.6	6,550	138	52	891
Canned tomatoes, - - -	1.0	.2	3.7	10,205	102	20	378
Tapioca, corn starch, etc.,	—	—	97.8	810	—	—	792
Hominy, - - -	8.3	.4	77.4	1,530	127	6	1,184
Graham flour, - - -	11.7	1.7	71.7	2,805	328	48	2,011
Wheat flour (<i>a</i>), - - -	13.4	1.2	72.4	76,655	10,272	920	55,498
Entire wheat flour (<i>a</i>), -	15.4	1.9	69.8	4,790	738	91	3,343
Corn meal, - - -	9.2	3.8	70.6	2,185	201	83	1,543
Oat meal (<i>a</i>), - - -	15.3	7.5	65.7	3,630	555	272	2,385
Cracked wheat, etc., -	11.9	1.7	74.6	2,075	247	35	1,548
Macaroni, - - -	13.5	.4	75.4	625	84	3	471
Rice, - - -	7.4	.4	79.4	1,420	105	6	1,127
Lima beans, - - -	7.1	.7	22.0	1,900	135	13	418
Dried beans, - - -	23.1	2.0	59.2	2,950	681	59	1,746
Banana, pulp, - - -	1.4	1.4	29.8	7,640	107	107	2,277
Pine apple, - - -	.4	.3	9.7	3,105	12	9	301
Currants and raisins, -	2.7	.7	71.6	1,075	29	8	770
Prunes, etc., - - -	2.2	.5	66.5	5,075	112	25	3,380
Citron, - - -	.4	.6	72.4	455	2	3	329
Dates, - - -	2.2	5.1	70.4	905	20	46	637
Chocolate, - - -	6.8	21.0	67.6	480	33	101	324
Crackers, - - -	9.3	13.1	69.2	11,795	1,097	1,545	8,162
Cake, - - -	8.3	10.8	57.8	2,620	217	283	1,514
Bread, - - -	9.1	1.6	56.0	6,735	613	1,078	3,772
Sugar, granulated, - - -	—	—	100.0	34,105	—	—	34,105
Molasses, etc., - - -	—	—	72.0	5,105	—	—	3,676
Total vegetable food, -	—	—	—	346,895	18,817	5,293	153,996
Total animal and vege- table food, - - - }	—	—	—	621,380	55,486	80,190	154,754
Refuse (<i>a</i>) - - -	24.5	29.5	38.5	50,490	12,370	14,894	19,438

TABLE 59.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a College Ladies' Eating Club.

FOOD MATERIALS.		NUTRIENTS.			Fuel Value.
		Protein.	Fat.	Carbo- hydrates.	
<i>For Club, 10 Days.</i>		Grams.	Grams.	Grams.	Calories.
Food purchased, -	Animal, -	36,669	74,897	758	850,000
	Vegetable, -	18,817	5,293	153,996	757,800
	Total, -	55,486	80,190	154,754	1,607,800
Waste, - - -	Animal, -	10,809	13,014	—	165,350
	Vegetable, -	1,561	1,880	19,438	103,580
	Total, -	12,370	14,894	19,438	268,930
Food actually eaten, -	Animal, -	25,860	61,883	758	684,650
	Vegetable, -	17,256	3,413	134,558	654,220
	Total, -	43,116	65,296	135,316	1,338,870
<i>Per Man Per Day.</i>					
Food purchased, -	Animal, -	89	183	2	2,070
	Vegetable, -	46	13	375	1,850
	Total, -	135	196	377	3,920
Waste, - - -	Animal, -	26	31	—	400
	Vegetable, -	4	5	47	250
	Total, -	30	36	47	650
Food actually eaten, -	Animal, -	63	152	2	1,670
	Vegetable, -	42	8	328	1,600
	Total, -	105	160	330	3,270
<i>Percentages of Total Food Purchased.</i>					
Food purchased, -	Animal, -	66.1	93.4	.5	52.9
	Vegetable, -	33.9	6.6	99.5	47.1
	Total, -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, -	19.5	16.2	—	10.3
	Vegetable, -	2.8	2.3	12.6	6.4
	Total, -	22.3	18.5	12.6	16.7
Food actually eaten, -	Animal, -	46.6	77.2	.5	42.6
	Vegetable, -	31.1	4.3	86.9	40.7
	Total, -	77.7	81.5	87.4	83.3

No. 19.

DIETARY OF A SWEDE FAMILY.

The study began Oct. 1st, 1894, and lasted 7 days. The family was the same as in No. 15. The man was employed in the chemical laboratory. The meals taken were: Man, 21 meals; woman ($21 \times .8 =$) 17 meals; two girls ($42 \times .4 =$) 17 meals; child ($21 \times .25 =$) 5 meals. Total equivalent to 60 meals or 20 days for one man.

TABLE 60.

Food Materials and Table and Kitchen Wastes in Dietary of a Swede Family During Seven Days.

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbo- hydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
Round steak (a), - -	19.2	10.2	—	1,710	328	174	—
Bologna sausage (a), - -	27.6	32.6	3.9	385	106	126	15
Mutton leg (a), - - -	19.0	11.5	—	1,075	203	123	—
Pork chops, - - - -	14.0	24.6	—	765	107	188	—
Salt pork (a), - - - -	4.6	91.7	—	255	12	234	—
Smoked ham (a), - - -	32.6	12.8	—	580	189	234	—
Lard, - - - - -	—	99.8	—	255	—	254	—
Milk (a), - - - - -	3.7	2.3	4.4	14,160	524	326	623
Condensed milk, - - -	11.8	10.4	50.1	455	54	47	228
Butter, - - - - -	—	85.0	—	650	—	553	—
Eggs, - - - - -	14.9	10.5	—	1,120	167	118	—
Total animal food, - -	—	—	—	21,410	1,690	2,377	866
VEGETABLE FOOD.							
Potatoes (40 % refuse), -	2.1	.1	17.9	3,690	78	4	660
Turnips (30 % refuse), -	1.2	.2	8.2	466	6	9	38
Onions (10 % refuse), -	1.4	.3	10.1	392	5	1	40
Flour (a), - - - - -	12.5	1.2	74.8	4,850	606	58	3,628
Rye flour, - - - - -	6.7	.8	78.7	395	26	3	311
Wheat bread, - - - -	9.1	1.6	56.0	1,430	130	23	801
Mince meat, - - - - -	4.0	2.2	67.4	255	10	6	172
Milk crackers, - - - -	9.3	13.1	69.2	425	40	56	294
Rolled oats (a), - - -	15.1	8.8	66.1	170	26	15	112
Corn meal, - - - - -	9.2	3.8	70.6	225	21	9	159
Dried beans, - - - - -	23.1	2.0	59.2	285	66	6	169
Sugar, - - - - -	—	—	100.0	4,675	—	—	4,675
Molasses, - - - - -	—	—	72.0	1,005	—	—	724
Rice, - - - - -	7.4	.4	79.4	370	27	1	294
Chocolate, - - - - -	6.8	21.0	67.6	115	8	24	78
Total vegetable food, -	—	—	—	18,748	1,049	215	12,155
Total food, - - - - -	—	—	—	40,158	2,739	2,592	13,021
Table and kitchen waste (a),	14.4	21.6	56.2	532	77	115	299
Fat from kitchen waste, -	—	100.0	—	13	—	13	—
Total, - - - - -	—	—	—	545	77	128	299

TABLE 61.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Swede Family.

FOOD MATERIALS.				NUTRIENTS.			Fuel Value.
				Protein.	Fat.	Carbo- hydrates.	
<i>For Family, 7 Days.</i>				Grams.	Grams.	Grams.	Calories
Food purchased,	{	Animal, -	-	1,690	2,377	866	32,580
		Vegetable, -	-	1,049	215	12,155	56,130
		Total, -	-	2,739	2,592	13,021	88,710
Waste, - - -	{	Animal, -	-	51	123	—	1,350
		Vegetable, -	-	26	5	299	1,380
		Total, -	-	77	128	299	2,730
Food actually eaten, -	{	Animal, -	-	1,639	2,254	866	31,230
		Vegetable, -	-	1,023	210	11,856	54,750
		Total, -	-	2,662	2,464	12,722	85,980
<i>Per Man Per Day.</i>							
Food purchased,	{	Animal, -	-	85	118	43	1,630
		Vegetable, -	-	52	11	608	2,810
		Total, -	-	137	129	651	4,440
Waste, - - -	{	Animal, -	-	3	6	—	70
		Vegetable, -	-	1	—	15	70
		Total, -	-	4	6	15	140
Food actually eaten, -	{	Animal, -	-	82	112	43	1,560
		Vegetable, -	-	51	11	593	2,740
		Total, -	-	133	123	636	4,300
<i>Percentages of Total Food Purchased.</i>							
Food purchased,	{	Animal, -	-	61.7	91.7	6.7	36.7
		Vegetable, -	-	38.3	8.3	93.3	63.3
		Total, -	-	100.0	100.0	100.0	100.0
Waste, - - -	{	Animal, -	-	1.9	4.7	—	1.5
		Vegetable, -	-	.9	.2	2.3	1.6
		Total, -	-	2.8	4.9	2.3	3.1
Food actually eaten, -	{	Animal, -	-	59.8	87.0	6.7	35.2
		Vegetable, -	-	37.4	8.1	91.0	61.7
		Total, -	-	97.2	95.1	97.7	96.9

No. 20.

DIETARY OF THREE CHEMISTS.

The study began Oct. 10, 1894, and continued 10 days. The three men were 28, 26, and 23 years old, respectively. They were at regular work in the laboratory, and were at the same time pursuing other studies in chemistry. They may be regarded as having very light muscular exercise. The number of meals taken were 90, or equivalent to 30 days for one man.

TABLE 62.

Food Materials and Table and Kitchen Wastes in Dietary of Three Chemists During Ten Days.

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo-hydrates.
ANIMAL FOOD.	%	%	%	Grams.	Grams.	Grams.	Grams.
<i>Beef.</i>							
Shoulder steak (a), - -	17.0	14.6	—	345	59	50	—
Shoulder steak (a), - -	15.4	7.1	—	480	74	34	—
Shoulder steak (a), - -	14.9	5.9	—	355	53	21	—
Shoulder steak (a), - -	16.2	5.6	—	495	80	28	—
Rib roast (a), - - -	17.0	9.0	—	765	130	60	—
Rib roast (a), - - -	17.1	8.5	—	1,035	177	88	—
Rib roast (a), - - -	13.1	6.8	—	565	74	38	—
Canned corned beef (a), -	28.1	16.4	—	470	132	77	—
Total beef, - - -	—	—	—	4,510	779	405	—
Veal rib (a), - - -	15.3	2.5	—	865	132	216	—
Veal rib (a), - - -	12.4	3.4	—	640	79	22	—
Total veal, - - -	—	—	—	1,505	211	238	—
<i>Pork.</i>							
Smoked ham (a), - - -	19.0	22.3	—	355	67	79	—
Smoked ham (a), - - -	17.0	14.5	—	270	46	39	—
Smoked ham (a), - - -	17.7	18.5	—	200	35	37	—
Salt pork (a), - - -	2.0	94.1	—	255	51	240	—
Total pork, - - -	—	—	—	1,080	199	395	—
Cottolene (a), - - -	—	100.0	—	905	—	905	—
<i>Fish, etc.</i>							
Fresh cod steaks (a), - -	16.9	.5	—	665	112	3	—
Oysters, "solids" (a) - -	6.1	1.0	1.9	525	32	5	10
<i>Dairy Products.</i>							
Milk (a), - - -	3.3	4.6	5.2	84,035	277	387	437
Cream (a), - - -	3.1	16.8	3.2	1,490	46	250	48
Butter (a), - - -	.7	84.2	—	2,280	16	1,920	5

TABLE 62.—(Continued.)

FOOD MATERIALS.	PERCENTAGE COMPOSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbohy- drates.
ANIMAL FOOD.—(Con.)	%	%	%	Grams.	Grams.	Grams.	Grams.
Cream cheese (a), - -	23.9	30.2	8.8	510	122	154	45
Eggs (a), - - - -	15.5	11.8	—	1,390	215	164	—
Total, - - - -	—	—	—	89,705	676	2,875	535
Total animal food, - -	—	—	—	98,895	2,009	4,826	545
VEGETABLE FOOD.							
Potatoes, flesh (a), - -	2.4	.1	16.9	6,415	115	6	1,039
Sweet potatoes, flesh (a), - -	.9	.3	28.6	7,555	68	23	216
Turnips, flesh (a), - -	1.0	.4	5.3	2,950	30	12	156
Squash, flesh (a), - -	1.2	.8	10.4	1,760	21	14	183
Apples, flesh, - - -	.5	.7	16.0	4,960	25	35	794
Bread flour (a), - - -	13.4	1.1	74.4	4,565	612	50	3,397
Pastry flour (a), - - -	11.6	.9	74.5	1,885	219	17	1,404
Granulated sugar, - - -	—	—	100.	4,255	—	—	4,255
Rolled oats (a), - - -	18.3	7.2	66.1	1,090	199	79	720
Corn meal (a), - - -	8.8	1.6	80.3	765	67	122	614
Dried beans, white (a), -	23.8	1.8	58.9	695	165	13	409
Dessicated cocoanut (a), -	6.5	64.1	24.3	45	3	29	11
Macaroni (a), - - -	14.4	1.0	73.1	395	57	4	289
Tapioca (a), - - -	.3	.1	88.4	130	4	1	115
Milk crackers, - - -	9.3	13.1	69.2	555	52	73	384
Total, - - - -	—	—	—	38,020	1,637	478	13,986
Total animal and vegetable } food, - - - -	—	—	—	136,915	3,646	5,304	14,531
Table and kitchen waste (a), -	16.9	25.4	49.4	963	162	196	476

TABLE 63.

Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of Three Chemists.

FOOD MATERIALS.		NUTRIENTS.			Fuel Value.
		Protein.	Fat.	Carbo- hydrates.	
<i>For Three Men, 10 Days.</i>		Grams.	Grams.	Grams.	Calories.
Food purchased, -	Animal, - -	2,009	4,826	545	55,360
	Vegetable, - -	1,637	478	13,986	68,500
	Total, - -	3,646	5,304	14,531	123,860
Waste, - - -	Animal, - -	106	180	—	2,110
	Vegetable, - -	56	16	476	2,340
	Total, - -	162	196	476	4,450
Food actually eaten, -	Animal, - -	1,903	4,646	545	53,250
	Vegetable, - -	1,531	462	13,510	66,160
	Total, - -	3,484	5,108	14,055	119,410
<i>Per Man Per Day.</i>					
Food purchased, -	Animal, - -	67	161	17	1,845
	Vegetable, - -	55	16	466	2,285
	Total, - -	122	177	483	4,130
Waste, - - -	Animal, - -	4	6	—	70
	Vegetable, - -	2	1	16	80
	Total, - -	6	7	16	150
Food actually eaten, -	Animal, - -	63	155	17	1,775
	Vegetable, - -	53	15	450	2,205
	Total, - -	116	170	467	3,980
<i>Percentages of Total Food Purchased.</i>					
Food purchased, -	Animal, - -	55.1	91.0	3.8	44.7
	Vegetable, - -	44.9	9.0	96.2	55.3
	Total, - -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, - -	2.9	3.4	—	1.7
	Vegetable, - -	1.5	.3	3.3	1.9
	Total, - -	4.4	3.7	3.3	3.6
Food actually eaten, -	Animal, - -	52.2	87.6	3.8	43.0
	Vegetable, - -	43.4	8.7	92.9	53.4
	Total, - -	95.6	96.3	96.7	96.4

No. 21.

DIETARY OF A MECHANIC'S FAMILY.

The study began Nov. 13, 1894, and continued 10 days. The members of the family and number of meals taken were as follows:

Man, about 32 years old, 26 meals.

Woman, about 29 years old (assumed = .8 of one man), $29 \times .8 = 23$ meals.

Woman, about 52 years old (assumed = .8 of one man), $30 \times .8 = 24$ meals.

Total equivalent to 73 meals or 24 days for one man.

TABLE 64.

Food Materials and Table and Kitchen Wastes in Dietary of a Mechanic's Family During Ten Days.

FOOD MATERIALS.	PERCENTAGE COM- POSITION.			WEIGHTS USED.			
	Protein.	Fat.	Carbohydrates.	Total Food Materials.	Nutrients.		
					Protein.	Fat.	Carbo- hydrates.
	%	%	%	Grams.	Grams.	Grams.	Grams.
ANIMAL FOOD.							
Beef, round (a), - - -	19.7	4.8	—	1,445	285	69	—
Beef, round (a), - - -	18.0	8.4	—	595	107	50	—
Beef, porter house (a), - -	11.6	10.2	—	725	84	74	—
Veal, rib roast (a), - - -	15.5	8.6	—	1,135	176	98	—
Veal, loin (a), - - -	21.4	1.5	—	185	40	28	—
Lard, - - - - -	—	99.8	—	255	—	254	—
Cottolene, - - - - -	—	100.0	—	285	—	285	—
Oysters, "solids," - - -	6.3	1.6	4.0	905	57	14	36
<i>Dairy Products, Etc.</i>							
Milk (a), - - - - -	3.9	4.8	4.5	10,165	396	488	457
Buttermilk, - - - - -	2.4	.3	4.1	1,077	26	3	44
Butter (a), - - - - -	.7	85.5	—	1,345	9	1,150	—
Eggs, - - - - -	14.9	10.5	—	1,275	190	134	—
Total animal food, - - -	—	—	—	19,392	1,370	2,647	537
VEGETABLE FOOD.							
Potatoes (15 per cent. refuse),	2.1	.1	17.9	5,300	111	5	948
Sweet potatoes (12 1/2 % refuse),	1.5	.4	26.0	785	12	3	204
Cooked squash, - - -	.9	.5	11.8	370	3	2	44
Apples (25 % refuse), - - -	.3	.4	15.9	7,935	24	32	1,262
Pasta flour (a), - - -	11.8	1.2	74.0	580	68	7	429
Bread flour (a), - - -	13.5	1.2	73.5	5,445	735	65	4,002
Rolled oats (a), - - -	14.6	7.4	68.0	130	19	10	88
Wheat germ meal (a), - - -	11.4	2.2	73.7	385	44	8	284
Rice, - - - - -	7.4	.4	79.4	200	15	1	150
Corn starch, etc., - - -	—	—	97.3	45	—	—	44
Granulated sugar, - - -	—	—	100.0	2,155	—	—	2,155
Prunes and dates, - - -	2.2	.5	66.6	450	10	2	300
Celery, - - - - -	1.6	.8	6.0	865	14	7	52
Bread, - - - - -	9.1	1.6	56.0	255	23	4	143
Milk crackers, - - -	9.3	13.1	69.2	325	30	43	225
Maple syrup, - - - - -	4.4	—	65.5	680	30	—	445
Total vegetable food, - - -	—	—	—	25,995	1,138	189	10,775
Total animal and vegetable food, - - - - -	—	—	—	45,297	2,508	2,836	11,312
Table and kitchen wastes (a),	35.8	41.0	17.2	199	71	82	34
Fat, - - - - -	—	100.0	—	115	—	115	—
Total, - - - - -	—	—	—	314	71	197	34

TABLE 65.

Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Mechanic's Family.

FOOD MATERIALS.		NUTRIENTS.			Fuel Value.
		Protein.	Fat.	Carbo- hydrates.	
<i>For Family, 10 Days.</i>		Grams.	Grams.	Grams.	Calories.
Food purchased,	Animal, - -	1,370	2,647	537	32,430
	Vegetable, - -	1,138	189	10,775	50,600
	Total, - -	2,508	2,836	11,312	83,030
Waste, - - -	Animal, - -	68	196	—	2,105
	Vegetable, - -	3	1	34	155
	Total, - -	71	197	34	2,260
Food actually eaten,	Animal, - -	1,302	2,451	537	30,305
	Vegetable, - -	1,135	188	10,741	50,465
	Total, - -	2,437	2,639	11,278	80,770
<i>Per Man Per Day.</i>					
Food purchased,	Animal, - -	65	126	26	1,545
	Vegetable, - -	53	9	513	2,410
	Total, - -	118	135	539	3,955
Waste, - - -	Animal, - -	3	9	—	100
	Vegetable, - -	—	—	2	5
	Total, - -	3	9	2	105
Food actually eaten,	Animal, - -	62	117	26	1,445
	Vegetable, - -	53	9	511	2,405
	Total, - -	115	126	537	3,850
<i>Percentages of Total Food Purchased.</i>					
Food purchased,	Animal, - -	54.6	93.3	4.8	39.1
	Vegetable, - -	45.4	6.7	95.2	60.9
	Total, - -	100.0	100.0	100.0	100.0
Waste, - - -	Animal, - -	2.7	6.9	—	2.6
	Vegetable, - -	.1	—	.3	.2
	Total, - -	2.8	6.9	.3	2.8
Food actually eaten,	Animal, - -	51.8	86.4	4.8	36.5
	Vegetable, - -	45.4	6.7	94.9	60.7
	Total, - -	97.2	93.1	99.7	97.2

TABLE 66.

Summary of Results of Dietary Studies made by the Station. Food per Man per Day.

DIETARIES.					NUTRIENTS.			Fuel Value.
					Protein.	Fat.	Carbo- hydrates.	
1. <i>Dietary of a Boarding House.*</i>					Grams.	Grams.	Grams.	Calories.
Food,	{	Purchased,	-	-	126	188	426	4,010
		Waste,	-	-	23	36	25	520
		Eaten,	-	-	103	152	401	3,490
2. <i>Dietary of a Chemist's Family.*</i>								
Food purchased,					118	103	430	3,210
3. <i>Dietary of a Jeweler's Family.†</i>								
Food,	{	Purchased,	-	-	91	126	483	3,530
		Waste,	-	-	8	9	5	140
		Eaten,	-	-	83	117	478	3,390
4. <i>Dietary of a Blacksmith's Family.†</i>								
Food,	{	Purchased,	-	-	103	176	408	3,730
		Waste,	-	-	3	5	7	90
		Eaten,	-	-	100	171	401	3,640
5. <i>Dietary of a Machinist's Family.†</i>								
Food,	{	Purchased,	-	-	100	159	427	3,640
		Waste,	-	-	1	3	6	60
		Eaten,	-	-	99	156	421	3,580
<i>Two Dietaries of a Mason's Family.†</i>								
6. December, 1892.								
Food,	{	Purchased,	-	-	107	153	391	3,470
		Waste,	-	-	3	5	16	120
		Eaten,	-	-	104	148	375	3,350
10. May, 1893.†								
Food,	{	Purchased,	-	-	125	145	366	3,365
		Waste,	-	-	6	8	18	175
		Eaten,	-	-	119	137	348	3,190
<i>Average of 6 and 10.</i>								
Food,	{	Purchased,	-	-	116	149	379	3,420
		Waste,	-	-	5	6	17	150
		Eaten,	-	-	111	143	362	3,270
7. <i>Dietary of a Carpenter's Family.†</i>								
Food,	{	Purchased,	-	-	125	152	498	3,970
		Waste,	-	-	11	17	23	300
		Eaten,	-	-	114	135	475	3,670
<i>Two Dietaries of a Carpenter's Family.</i>								
8. November, 1892.†								
Food,	{	Purchased,	-	-	107	161	408	3,610
		Waste,	-	-	7	12	20	220
		Eaten,	-	-	100	149	388	3,390

TABLE 66.—(Continued.)

DIETARIES.						NUTRIENTS.			Fuel Value.
						Protein.	Fat.	Carbo- hydrates.	
						Grams.	Grams.	Grams.	Calories.
11. May, 1893.†									
Food,	{	Purchased,	-	-	-	115	125	346	3,055
		Waste,	-	-	-	4	3	10	96
		Eaten,	-	-	-	111	122	336	2,965
<i>Average of 8 and 11.</i>									
Food,	{	Purchased,	-	-	-	111	144	377	3,335
		Waste,	-	-	-	6	8	15	150
		Eaten,	-	-	-	105	136	362	3,185
<i>Two Dietaries of Station Agriculturist's Family.‡</i>									
9. Winter, 1893.									
Food,	{	Purchased,	-	-	-	106	145	405	3,450
		Waste,	-	-	-	7	6	7	115
		Eaten,	-	-	-	99	139	398	3,335
13. Summer, 1893.									
Food,	{	Purchased,	-	-	-	133	150	475	3,885
		Waste,	-	-	-	4	5	3	85
		Eaten,	-	-	-	129	145	472	3,800
<i>Average of 9 and 13.</i>									
Food,	{	Purchased,	-	-	-	120	147	440	3,670
		Waste,	-	-	-	6	5	5	100
		Eaten,	-	-	-	114	142	435	3,570
12. <i>Dietary of a Student's Club.‡</i>									
Food,	{	Purchased,	-	-	-	113	180	376	3,680
		Waste,	-	-	-	19	39	30	570
		Eaten,	-	-	-	94	141	346	3,110
14. <i>Dietary of a Widow's Family.§</i>									
Food,	{	Purchased,	-	-	-	119	115	512	3,655
		Waste,	-	-	-	3	4	12	110
		Eaten,	-	-	-	116	111	500	3,545
<i>Two Dietaries of a Swede Family.§</i>									
15. March, 1894.									
Food,	{	Purchased,	-	-	-	121	116	473	3,610
		Waste,	-	-	-	3	4	7	80
		Eaten,	-	-	-	118	112	466	3,530
19. November, 1894.									
Food,	{	Purchased,	-	-	-	137	129	651	4,440
		Waste,	-	-	-	3	6	15	140
		Eaten,	-	-	-	133	123	636	4,300
<i>Average of 15 and 19.</i>									
Food,	{	Purchased,	-	-	-	129	118	562	4,030
		Waste,	-	-	-	3	5	11	910
		Eaten,	-	-	-	126	113	551	3,920

TABLE 66.—(Continued.)

DIETARIES.					NUTRIENTS.			Fuel Value.
					Protein.	Fat.	Carbo- hydrates.	
					Grams.	Grams.	Grams.	Calories.
16. <i>Dietary of a College Club.</i> §								
Food,	{	Purchased,	-	-	113	160	343	3,500
	{	Waste,	-	-	9	24	17	330
	{	Eaten,	-	-	104	136	326	3,170
17. <i>Dietary of a Divinity School Club.</i> §								
Food,	{	Purchased,	-	-	139	185	356	3,745
	{	Waste,	-	-	17	47	39	660
	{	Eaten,	-	-	122	138	317	3,085
18. <i>Dietary of a College Ladies' Eating Club.</i> §								
Food,	{	Purchased,	-	-	135	196	377	3,920
	{	Waste,	-	-	30	36	47	650
	{	Eaten,	-	-	105	160	330	3,270
20. <i>Dietary of Three Chemists.</i> §								
Food,	{	Purchased,	-	-	122	177	483	4,130
	{	Waste,	-	-	6	7	16	150
	{	Eaten,	-	-	116	170	467	3,980
21. <i>Dietary of a Carpenter's Family.</i> §								
Food,	{	Purchased,	-	-	118	135	539	3,955
	{	Waste,	-	-	3	9	2	105
	{	Eaten,	-	-	115	126	537	3,850
Food eaten,	{	Minimum of above,	-	-	83	103	317	2,965
	{	Maximum of above,	-	-	133	171	636	4,300
	{	Average of above,	-	-	110	138	421	3,469
<i>Dietary Standards for Men at Moderate Work.</i>								
Voit (German),					118	50	500	3,060
Atwater (American),					125	125	450	3,520

* Report of this Station, 1891, pp. 90-106.

† Report of this Station, 1892, pp. 135-162.

‡ Report of this Station, 1893, pp. 174-190.

§ There was very little waste in this dietary.

§ This Report, pp. 174-201.

STANDARDS FOR RATIONS AND DIETARIES.

BY W. O. ATWATER.



Some twenty years ago, at the Woodstock meeting of the Connecticut State Board of Agriculture in December, 1874, it was the writer's privilege to read a paper on the "Results of Late European Experiments on the Feeding of Cattle." A year before, the same subject was presented, though in less detail, at a meeting of the Maine State Board of Agriculture. These were, so far as I am aware, the first attempts in the English language to explain the theory of cattle-feeding which had become current in Germany, and to set forth the standards for rations already more or less in vogue in that country. In a paper on "The Chemistry of Foods," read at the meeting of the Connecticut Board of Agriculture in December, 1884, a brief statement was made of the main results of inquiry up to that time regarding the food and nutrition of man, with especial reference to the chemical composition of food materials and the quantities appropriated for the nutrition of people of different classes under different circumstances. Although the standards for daily dietaries there set forth had appeared in print in English before, I am not aware that they had been explained as fully as was done even in the short, popular paper just referred to.

The purpose of citing these incidents is to call attention to the short period during which the standards for rations for domestic animals and for dietaries for man, now so widely current in the United States, have been before the English reading public. The rapidity with which they have come into notice, their very general adoption in this country by writers upon the subject, by teachers, and by experimenters, and the extent to which they have become a part of the familiar knowledge of intelligent, practical men and women is, it seems to me, not only an interesting phenomenon, but an auspicious omen also, for the progress of the higher knowledge, as applied to the arts and industries of life in the United States.

The remark was lately made in the presence of a well-known Connecticut farmer that such expressions as protein, fat and carbohydrates, nutritive ratios, and standards for daily rations, which are to-day very familiar in the columns of the papers and in the discussions in agricultural meetings, were Greek to farmers in our State twenty years ago. "Say Sanskrit," said he. "We knew then that there was such a language as Greek, but we had never heard of these things." Nowadays the papers that treat of dairying and cattle-feeding refer to protein and carbohydrates and feeding standards as familiarly as to Jerseys, silos, and cotton seed meal. Not only that, but people are becoming interested to know the composition and properties of human food. Standards for daily dietaries are being widely quoted as authoritative, and, what is even more to the point, the United States Congress has provided an appropriation to be used for investigations of the economy of the food of man, based upon the same principle as the studies that are carried out by our Experiment Stations upon the food and nutrition of domestic animals. The eagerness of a large and rapidly increasing body of people to get hold of the statistics of the composition of food and of daily rations, standards for dietaries and the like, is interesting as it is encouraging. All this, it seems to me, marks the beginning of a hygienic and economic improvement, if not reform, in our food economy.

For all this progress, wide spread, rapid, and I may add inspiring, let us be profoundly thankful. If the twenty years just passed have seen so much accomplished, what may not be hoped for in the twenty years to come?

But this subject has another side. The modern doctrine of food and nutrition as applied to the nourishment of domestic animals and man is in danger of being misapplied. Indeed, it is being misapplied and to an extent already serious. To one who may claim to be a veteran in the campaign for the advance of research and of knowledge in these directions in the United States, it may be permitted to sound a note of warning.

The evils are practically three; the failure to recognize what feeding and dietary standards are and ought to be, the setting up of incorrect standards, and the blind and thoughtless use of such standards in the calculating of rations and dietaries. I will speak of these in the inverse order, taking the last first.

WRONG USE OF FEEDING STANDARDS.

The thing against which I wish to protest first of all is the inconsiderate use of feeding standards. To read articles which appear by the hundred, not only in the columns of the press, but even in some of our Experiment Station Reports, one would think that the science of cattle-feeding was a branch of applied mathematics, the data for calculations being found in the tables for composition of feeding stuffs, and the formulas in feeding standards. We are told, practically, with a constancy of repetition which is worse than tiresome, that for feeding a milch cow, for instance, we want per thousand pounds of live weight so and so many pounds of protein and other nutrients per day; that different feeding stuffs contain such and such percentages, that is to say, so and so many pounds per hundred of these nutrients; and that, to get a proper daily ration for a cow we must first select our food materials, then take their proportions of nutrients, and figure out quantities that fit the standard. By this calculation, which is perhaps a little abstruse to the average dairyman, but in which to-day there is no lack of mathematicians, chemists, and physiologists to help him, he may easily make his calculations; or, if he does not care to take this trouble, he may find them ready made and in the greatest abundance.

I am well aware that to say this and to put it so strongly is to expose myself to the severe charge of being the first man on this side of the Atlantic to use this method of calculating rations. It may be very true that the enthusiastic young student, fresh from studies in Europe, where this doctrine originated, was indiscreet in not emphasizing more clearly than he did that standards for rations are only approximations, and very rough ones at that; that at best they could only represent very general averages; that the variation in the composition of food stuffs of the same kind were so wide that no averages of analyses could apply to all cases; that the analyses were extremely imperfect representations of actual nutritive values; that we did not know exactly how the nutrients are used in the body; that it is impossible to lay down an accurate physiological standard for animals of any given kind; that differences, not only of species and of breed but differences of individuals of the same breed are so wide as to make an accurate physiological standard out of the question; and that even if the physiological standard were rightly determined the

feeding of domestic animals for profit involves consideration of the cost of the raw material, namely, the food; the cost of the machine and its running, the animal and its care; and the value of the product, be it growth, meat, milk or work. But he had taken the pains to talk with some practical men as well as with chemists, physiologists and experts, upon the subject, in Europe and especially in Germany. He had gathered the ideas just suggested and he did try, however imperfectly, to insist upon these cautions while attempting to explain the fundamental principles of nutrition, the composition of foods and feeding stuffs and the use of standards for rations and dietaries. And it is with a sentiment akin to pain that he peruses the statements so constantly reiterated, in so many places, by so many men, and with so little qualification; implying that there is something absolute in feeding standards and in tables of composition of feeding stuffs and that what the feeder has to do is to consult his feeding standard and his tables of composition, apply his mathematics, feed his cattle accordingly, and then hope for profit.

Analyses of feeding stuffs and feeding standards are useful, incalculably so. I venture the assertion that, aside from improved breeds, the thing which has done most to help the stock grower and the dairymen in our older States is the improved system of feeding which the use of this very doctrine has done more than anything else to bring about. The danger is in the blind, unthinking use of the theory.

THE SETTING UP OF WRONG STANDARDS.

The formulas for rations of domestic animals most commonly quoted are those of the German experimenter, Wolff. One reason for the popularity of Wolff's formulas, and perhaps the chief, is that they are so simple and so easily quoted and followed. Another is doubtless found in the fact that they have so long been a feature of the famous German Farmers' Almanac (*Mentzel und v. Lengerke's Landwirtschaftlicher Kalender*), which in that country is much more common among farmers than the Bible and, it is to be feared, much more consulted by them. The less definite and more conservative formulas and tables of composition of feeding stuffs of Julius Kühn* are more generally

* See Kühn's discussion of the subject of feeding standards in Experiment Station Record, volume IV., page 11.

accepted by experts in Germany than those of Wolff. Kühn urges the un wisdom of setting up standards as in any wise absolute, and calls especial attention to the difficulties in the way of assuming the composition of feeding stuffs from averages of analyses. He insists upon the great values of feeding standards and of their use in connection with the estimates of composition of feeding stuffs, but urges with emphasis the necessity of studying the individual animal and fitting the food to the observed needs rather than to any arbitrary standard. Wolff, of course, assents to these principles in a general way, and would, I am sure, protest emphatically against considering either his formulas or those of Kühn, or any others, as more than rough approximations and averages.

The following is from comments by the writer upon Prof. Kühn's article above referred to:

"Prof. Kühn calls attention to several difficulties in the way of prescribing definite feeding standards for different classes of animals which are fed for different purposes. They have to do with the animals, the feeding stuffs, and the commercial value of the feeding stuffs and the products.

"In the first place different animals of the same class differ greatly in their capacity for utilizing food, and even the same animal may require different rations under different conditions. Thus different breeds of milch cows and different cows of the same breed may vary widely with respect to the amounts of food which they can most advantageously utilize. The amount appropriate for 1,000 pounds live weight may be much greater with a small cow than with a large one. It varies with the bodily condition of the animal, whether lean or fat, and with the amount of the milk yield. The quantity of food needed depends also upon whether, as the milk falls off toward the end of the period of lactation, the cow is to be fattened for the butcher or is to be used again for breeding and milking. In brief, it is impossible to lay down hard and fast rules for quantities of food or quantities of nutrients, or for nutritive ratios to apply indiscriminately to different animals under different conditions.

"Again, different specimens of any kind of feeding stuff may vary widely in chemical composition so that the figures for average composition may be very far from the truth in a given case. The coefficients of digestibility are likewise variable. And even if the quantities of actually digestible nutrients in any given instance,

as determined by either natural or artificial digestion, should be taken as the basis of the calculation, they might be very far from expressing the nutritive value of the materials as they are actually utilized by the animal, because of the defects in our present methods of analysis and of classification of the nutrients.

“Finally, economical feeding is not simply a matter of fitting the nutrients of the food to the physiological demands, but of adjusting the kinds and quantities of feeding stuffs to their cost and to the amount and market value of the product.

“Prof. Kühn’s conclusion is that to calculate rations upon a basis of the feeding standards and the average composition of the feeding stuffs, is irrational and may be very unprofitable. He would, however, by no means give up either standards or tables of composition. As regards the quantities of nutrients to be fed, he would take into consideration the individual needs of each animal and make the quantities of total food and of the several nutrients such as will best fit the special demands of the animal for sustenance and production. In calculating the amounts of feeding stuffs to be used he would not simply use the average figures, but would consider the ranges of variation and the composition of the particular materials to be fed. The ideal method would be to analyze the feeding stuffs in each case, if this were practicable, but it usually is not. But along with the chemistry and physiology of the subject, the skill of the experienced practical feeder is absolutely essential. For the method of ‘individual feeding’ which Prof. Kühn recommends he gives suggestions of no little interest.

“One matter which Prof. Kühn rightly insists upon is the distinction between the digestible protein, *i. e.*, total digestible nitrogenous substances and the digestible actual albuminoids. He also urges with justice that the ether extract of the coarse fodders has a much lower feeding value than that of the concentrated fodders like oil cakes and meals, which consist mostly of the true fats. He insists with like good reason that what we call non-nitrogenous extract represents a great variety of materials unknown or of doubtful value.

“Chemists clearly apprehend the difficulty with their analysis as measures of the nutritive value of feeding stuffs, but the experimenters and writers have not always appreciated the full import of the differences in individuality of animals, nor has the importance of taking into account the condition of the

individual animal been generally realized. We have learned that there is very little use in preparing formulas for fertilizers for a given plant to be used on different soils. The reason is that soils vary so widely in chemical and physical characters. We are gradually coming to understand that the differences between individual animals of the same kind if not as large as those between different soils, are nevertheless much greater than we formerly supposed. This is a fact which must be taken into account both in our experimenting and in our practical feeding.

"One point which Prof. Kühn dwells upon is of especial interest. It is that in the feeding of milch cows the rations should be fitted to the production expected. Instead of a standard giving certain amounts of nutrients per thousand pounds of live weight, he proposes to use a basal ration, which will be a little more than a maintenance ration, and to add to this quantities of nutrients proportionate to the wants of each animal and the production expected.

"Feeding standards and tables of composition and digestibility are invaluable helps to economical feeding. There is every reason to believe that they will be made more and more useful as experimental inquiry brings us more and more exact information. But they are only helps. They are to be regarded as indications rather than rules. They can not take the place of the skill of the experienced practical feeder. In his treatise on cattle feeding, to which Prof. Kühn refers, and which ought to be better known than it is on this side of the Atlantic, the principle is expressed in the German adage, which is taken as the motto of the book: '*Das Auge des Herrn mästet sein Vieh*' (the eye of the master fattens his stock)."

Of late an attempt has been made in the United States to elaborate a feeding standard for milch cows.* This formula differs from those of Wolff and Kühn, mainly in providing less protein and more fats and carbohydrates. In other words, the nutritive ratio is much wider than in the formulas of Wolff and Kühn. A table comparing several different so-called "standard rations" may be found on page 46 of the present Report.

It may be that in one case Wolff's formula will be the best and in another the so-called "American standard ration," proposed by Prof. Woll, will be the best; that is to say, the most profitable

* See Woll; Bulletins of Wisconsin Experiment Station, No. 33 and No. 38.

for the feeder. But it is extremely probable that in the great majority of cases something different from either will be really most advisable, and wherever either one of these formulas is not the most advantageous, it is the wrong one. Doubtless it will be better for any given farmer to follow almost any of the proposed formulas rather than to let his feeding be entirely haphazard. A wrong formula may be a great deal better than none. Feeding towards Wolff's formulas has unquestionably been of immense advantage. The point I wish to urge is, that the right formula is the one that fits the individual case, and that the cases in which any given formula, be it that of Wolff, or of Kühn, or of Woll, is actually the best, are the exceptions rather than the rule.

THE PROPER SIGNIFICANCE OF FEEDING STANDARDS AND FORMULAS.

This brings us to the kernel of the whole subject. What is a feeding standard? To answer this we must first of all avoid a confusion of terms which has become common. We must distinguish between three different kinds of standards, or rather, since the word standard cannot be applied with equal propriety to all, we must distinguish between three different kinds of formulas which may be used to express quantities and proportions of nutrients for feeding. These may be designated as the physiological standard, the formula for profitable feeding, and the formula which expresses the actual practice of feeders.

PHYSIOLOGICAL STANDARDS.

The physiological standards would express the proportions of the different nutrients, protein, fats and carbohydrates which best fit the demands of the animal for the particular kind of product demanded of it, whether that product is growth, as in the case of young animals; or meat, as in the fattening of cattle, sheep and swine; or milk, with milch cows; or work, as with horses and oxen. In all of these cases a certain amount of nutrients is required for maintenance and a certain additional amount for production. The functions of the several classes of nutrients in meeting the demands for maintenance and production have been more or less definitely shown by feeding experiments, and we have to-day, as the result of a great deal of experimenting, somewhat of an idea of the relations between the physiological demands of an animal of a given class and fed for a given purpose

and of the quantities of nutrients needed to supply it. But, unfortunately, our knowledge in all these respects is still deficient, and furthermore the differences of individual animals of the same breed, to say nothing of the differences between animals of different breeds and species, are so wide that with the most perfect knowledge of the laws of nutrition it will hardly be possible to set up accurate physiological standards for large classes of animals. There is, however, the best ground to expect that a reasonable amount of experimenting of the right kind will bring us satisfactory information in this respect.

EXPERIMENTS NEEDED FOR PHYSIOLOGICAL STANDARDS.

The experimental inquiry needs to be of two kinds; accurate experiments in metabolism, and practical feeding trials. For the first it will be essential to take account of the income and outgo of the body of the animal, as expressed, not simply in terms of food and drink on one hand and of excreta, solid, liquid and gaseous on the other; but also in terms of chemical compounds and especially of chemical elements of the income and outgo. These will give the data for the metabolism of matter in the body. For the most desirable results, however, it will be necessary to go a step farther and take an account of the income and outgo of energy. The income of energy will be the potential energy of the food; the outgo of energy will be the potential energy of the unconsumed food, *i. e.*, that of the solid and liquid excreta, and the kinetic energy manifested in the heat diffused from the body and in the mechanical power of the muscular work performed.* In other words, we have to study the metabolism of energy as well as of matter.

Experimenting of this kind is very costly. It requires elaborate apparatus, the most skillful assistants, and very long time. The respiration calorimeter which is being elaborated at Wesleyan University in connection with the work of this Station, is intended for inquiries of this especial kind. Of course it is not necessary that a respiration calorimeter or even a respiration apparatus shall be used in all experimenting in metabolism. Much can be learned from feeding trials in which the income and outgo of only a single chemical element as nitrogen is determined. But the respiration apparatus, and especially the respiration calorimeter, must be looked to for the most accurate and decisive results.

* For detailed discussion of this particular subject see Bulletin No. 21 of the Office of Experiment Stations of the U. S. Department of Agriculture, entitled "Methods and Results of Investigations on the Chemistry and Economy of Food."

Another kind of experimenting and one which though its chief usefulness will be of a purely practical sort, will also bring results of physiological value, consists in feeding trials such as may be conducted in any well equipped experiment station in connection with a chemical laboratory. If, for instance, the subject be the effect of fodder upon milk production, rations differing in amount and composition may be fed and the amount and composition of milk determined. The difficulty with these experiments is that there are numerous other factors besides the food which affect the milk production and not all of these factors can be accurately estimated. But there is one way by which such experiments can be made very effective and useful. That is, duplication. One station alone cannot well do enough to settle any specific question, but by coöperation between different experiment stations a great deal could be accomplished. To make this coöperation successful it would be necessary to select narrow and specific questions, to decide upon a uniform plan, to use as many animals in each case as practicable and to make a large number of experiments in a number of different places. There is very little question that this would be the most economical and useful way to work. The dairy trials at the World's Fair brought results some of which were reasonably definite. In consequence they are of very great practical value. What gives them definiteness and value is that a large number of cows were used. It is not necessary that all the cows be in one place, but the "might of average figures" which can be almost said to "increase as the square of the number" is what makes the results reliable.

The series of coöperative experiments which have been conducted during the past twenty years in Germany and Denmark are a most valuable illustration of the usefulness of one way in which extensive feeding trials may be made useful.*

Both these kinds of experimenting are needed to give us a real physiological feeding standard, and when we get that standard we shall doubtless find that it is after all indefinite, that it varies with the animal as well as with the conditions of feeding; in other words, it will be at best only an average estimate and not an unvarying formula.

FORMULAS FOR PROFITABLE FEEDING.

But the practical feeder feeds for profit, and the ration which will produce the largest amount of growth, or of total flesh or of

* See Experiment Station Record, Vol. III., pp. 507, 557, and Vol. VI., p. 585.

lean or fat meat, or the largest amount of milk or butter-fat or enable the animal to do the largest amount of work from a given quantity of nutrients, is not always or generally the one which will bring the most profit to the feeder. In other words, the physiological standard may not be the most profitable formula for feeding. The factors of profit are numerous. One of the chief is the physiological action of the nutrients, but the cost of the food and the value of the product have to be taken into account. It may be to the feeder's advantage to use a wide ration when a narrow one would give more yield for less raw material. There is a very wide difference in respect to the width of ration between the physiological standards as we now understand them and the actual feeding practice of most American farmers, but it would be as wrong to advise them to conform exactly to the physiological standard as it would be to take the average of the practice of successful feeders, for either a physiological standard or a formula for profitable feeding.

To find the formulas for feeding profitably two kinds of observation and experimenting are especially needed. The first and simplest consists in accurate observation of the actual practice of feeders and comparison of their methods of feeding with the product. This is being done by the Storrs Station with results as described in the present and previous Reports. The results thus far obtained are few and in no way remarkable, but they do represent the beginning of an inquiry which, if carried out for a series of years and with a wider and wider range of animals, breeds and methods of feeding and with such constant improvement of method as experience suggests, cannot fail to bring useful results. The value of these results will be materially increased if opportunity is taken, after observations have been made, to test the effect of changes in the feeding upon the product, as has been done in a small number of experiments detailed in the Reports referred to. We do not claim at all that the plan adopted by this Station is the best. What I do urge, and that with emphasis, is that the principle is a good one, that as the number of observations and experiments increase the value of the results will increase in still greater ratio; and that it is eminently desirable that a number of Stations should unite in work of this kind. Not only is it useful for learning the actual feeding practice of farmers and for working toward profitable feeding formulas, but it is preëminently valuable as a means of

education to the farmer. When a series of accurate experiments is carried on with a man's own cows, in his own barn, and he shares in the work, sees how it is done, follows the details and studies the results, he gets a kind of knowledge which he could not get in any other way. His neighbors will see the experiments done and talk them over with him and with each other and will be likewise benefited, and when the results are published and read, farmers who have not seen the experiments read about them and realize that they come from a union of science with practice; that they represent what their brother farmers have done with the aid of the Station as well as what the Station has done with the aid of the farmer. They study the details, they reflect upon them, they criticise them, and sometimes with a wisdom and acuteness which is most valuable to the Station experimenters; and, what is best of all, they use the results to the advantage of brain as well as purse.

But while the deducing of formulas for profit may be helped by this kind of experimental observation, the most useful information will come from coöperative experiments of a more thorough sort such as the Stations can best carry out with their own herds and near their own laboratories.

And let me repeat that profit is a matter of cost of raw material and manufacture and value of product and that all of these factors are extremely variable. A profitable formula for one plan or time may be very unprofitable for another. A fixed formula for profit is utterly irrational.

In framing his standards for rations for domestic animals Wolff apparently had what I have here designated as physiological standards chiefly in mind, although he did not make the distinction I have insisted upon and he did keep in view the profit to be gained from feeding. Such at any rate is the impression which I think one would gain from a study of Wolff's writings at the time, and especially his statement of the considerations which led to his standards. The standards were printed in the Farmers' Calendar above referred to for 1864, and are there explained. Wolff's later discussions of the subject in his *Landwirtschaftliche Fütterungslehre* and *Ernährung der landwirtschaftlichen Nutzthiere* seem to me to imply the same view on his part. Kühn lays no less stress upon the physiological aspects of the question, but being a man of larger practical experience as a feeder, he emphasizes more than Wolff does the other conditions

which decide the profit of feeding. Both, however, make accurate experiment the principal basis of their calculations.

THE FEEDING PRACTICE OF FARMERS.

In the tabular statement on page 46 may be found results of the averages of 23 observations of methods of feeding actually practiced by dairymen in Connecticut, to which reference has just been made. The observations were made by representatives of the Station who visited each farm, and with the aid of the owner of the cows measured and weighed the food, took samples for analysis, and measured the milk and tested the quantities of fat by the Babcock method. The periods of observation were either five or twelve days each. Such observations, of course, leave much to be desired, but still the results do, without doubt, give at least a reasonably accurate idea of the actual usage of these feeders at the time when the observations were made. They doubtless diverge more or less in each case from the actual practice of feeding the herd for the season. But by repeating these observations from year to year on the same farms and on different farms, we shall gradually get more and more exact information as to how Connecticut farmers actually feed their cows, how much milk they get, and how much butter-fat it contains. Such observations collated and averaged will lead toward formulas for the actual practice of American feeders.

Another method for learning the practice of feeders has been adopted by other experiment stations and especially by two, the New York State, and the Wisconsin Station. The results of the observations by the Wisconsin Station are summarized on page 46 of the present Report, and on pages 94 to 101 of the Report of this Station for 1893. They may be found in detail in the Bulletin of the Wisconsin Station already cited. Messrs. Woods and Phelps have commented upon them in the present Report. They have also been referred to in the Experiment Station Record, Vol. VI., pages 350-352. It is not needful that I should add anything to the comments there made. The thing to be insisted upon here is that even if the average of the feeding practices of a larger or smaller number of feeders were made up from accurate observations it would be a mere chance if it were a correct formula for profit for any one of them, and that it would be still less apt to be the best formula for profitable feeding for other feeders under other conditions. The average of an indefinite number of

inaccurate observations of practices which is more or less erroneous, cannot represent the actual average practice and is still farther from indicating what is most profitable in any given case.

The editorial comments in the Experiment Station Record above referred to include the following opposite statements:

“The collection of statistics on the practice of feeding may be suggestive and useful in its way, but the error should not be made of supposing that a standard can be worked out in this manner. Thorough systematic feeding experiments by scientific experts alone can furnish the proper basis for American feeding standards. The experiments should be made in different parts of the country and continue through a number of years. They should be planned on a system which will make the results properly comparable, and the records should be accurately kept. Summaries of data obtained in this way and of the available data which we have now, would be fairly entitled to be called feeding standards. These standards would have a real value because they would be founded on scientific work and deductions. The closeness with which they would be followed by farmers in different parts of the country would, of course, depend on a number of variable conditions, as must be the case with any standard. With the further accumulation of feeding experiments, the standards would probably have to be somewhat modified and perfected.”

THE PLACE OF THE EXPERIMENTER AND THE PRACTICAL FEEDER.

Unquestionably the experience of practical feeders, and especially the experience of the most successful ones, is of the highest value. It is with the aid of such men that the doctrine of successful cattle feeding will be best worked out. The place of the chemist and physiologist is rather to explain the theory than to lay down rules for the practice of feeding. In developing his theory he will be most successful if he does as the most successful teachers, like Liebig, Henneberg, Kühn and Wolff in Germany, and Lawes and Gilbert in England, have done, namely, to make as accurate experiments and observations as possible and collate and explain their results as accurately and as simply as he can.

STANDARDS FOR DIETARIES.

In framing the standards for daily dietaries for human beings the same physiological principles apply as in the standards for rations for domestic animals.

But by as much as men and women are of more consequence than the animals subdued to their service, by so much is it more essential that the physiological demands should be chiefly considered in the arrangement of their dietaries. And it must be remembered that we are not able to say to-day with any degree of exactness just what is the measure of these physiological demands. Certain formulas have, indeed, been proposed for dietaries of men, women and children. I have ventured to discuss them in other places,* and will only say here that there seems to me to be the danger of their misuse. The danger is the same as in the case of standards for rations for domestic animals, namely, that of regarding them in the light of statistics and recipes to be blindly followed.

IN CONCLUSION.

In view of the interest in the economy of food for man which has lately manifested itself and is growing so rapidly, it seems to me proper to lay especial emphasis upon the fact that we have no dietary standards based upon at all satisfactory physiological data. The ones most commonly current are those of Voit and his school in Germany. In compiling these the results of the few accurate experiments available at the time were employed, but the chief stress was laid upon the observations of the quantities of food consumed, in Germany and especially in Bavaria, by persons whose conditions of life were such as to lead Voit and his followers to assume that their nourishment was normal. It is clear, however, that the eating habits of these people and of those with whom the more accurate experiments were made, and who also lived in Germany, were decided largely by their conditions. If the same observations and experiments had been made in Connecticut instead of Bavaria, it seems reasonably certain that the quantities of food consumed would have been much larger and the standards for dietaries based upon them would have been correspondingly larger than those of Voit and his school. It would be an evident mistake to accept these German standards as valid for general application. Indeed, there seems to me every reason to assume that they represent a scale of living decidedly lower than is desirable.

* See Report of Storrs Station, 1881, pages 144-161; and Bulletin No. 21 of the Office of Experiment Stations of the U. S. Department of Agriculture, on "Methods and Results of Investigation of the Chemistry and Economy of Food," pages 141-225.

SIMPLIFYING FORMULAS FOR RATIONS AND DIETARIES.

In concluding I venture to urge the desirability of simpler forms than have hitherto been current. Experimental science has brought us to the point where we may safely say that the uses of food are principally two: (1) To form the material of the body and repair its wastes; (2) to yield heat to keep the body warm and muscular and other power for the work which it has to do. In forming the tissues and fluids of the body the food serves for building and repair. In yielding heat and power it serves as fuel.

The different nutrients of the food serve the body in different ways. The principal tissue formers are the protein compounds, especially the albuminoids. These make the "flesh," and thus build up and repair the nitrogenous materials as the muscles and tendons. They also supply the albuminoids of blood, milk and other fluids. The chief fuel ingredients of the food are the carbohydrates and fat. These are either consumed in the body when the food is eaten or they are stored as fat to be used as occasion demands. The protein compounds can also serve as fuel. The carbohydrates and fats both serve for fat formation in the body. The protein, fats and carbohydrates in serving as fuel appear to replace one another in proportion to their potential energy or heats of combustion. While it is certain that the carbohydrates are transformed into fats, it is not definitely settled that in their capacity for forming the fat of the body or of the milk they stand in the same ratio to the fats of the food as does their potential energy to that of the fats. But it is reasonably probable, if not certain, that in their service for yielding heat and muscular power the value of the carbohydrates and fats is proportional to their potential energy.

It follows from this that for the ordinary purposes of nutrition the two principal factors of the food to be considered are the protein and the potential energy. To put it in another way, when the farmer feeds his stock he needs to use such kinds and amounts of food as will supply his animals the proper amounts of tissue formers and fuel values. It will be much simpler to explain the matter to him in this way than to go into the full details regarding protein, fats, carbohydrates, nitrogen-free extracts and the like. We may likewise express the formulas for rations and dietaries in terms of protein and energy or tissue

formers and fuel value. This I have attempted to do in other places.* It is done also in the pages of the present Report.

With regard to this whole matter there are two things to be especially remembered:

The first is that our tables of composition of foods and feeding stuffs and our formulas for rations and dietaries are only general indications. They are not maps, but guide posts. They are not recipes, but simply attempts to epitomize general principles. To use them rightly the principles must be understood, and in their application they must be fitted to the demands of individual cases.

The other is the need of research. A vast deal of time and thought and labor and money has been used, in this country and Europe, during the past fifty and especially the past thirty years, in attempting to learn the laws of nutrition of animals and man. The results of all this work are magnificent, and yet they are only preliminary. The time has come when three things are needed. These are: First, the collating of the results of inquiry and making them available to experimenters, teachers, students, writers, and the intelligent public; second, the systematizing of our so-called practical experimenting so that the work may be made coöperative, the results comparable, and the product more valuable; third, the developing of abstract inquiry.

This last, the abstract research, is the most difficult thing of all to accomplish. On that account, perhaps, it is the thing toward which we should strive most earnestly. What is wanted is the study of the application of the laws of the conservation of matter and the conservation of energy to the living organism, in order to discover more exactly the laws of nutrition; and the study of the chemistry and physiology of the materials used for foods and feeding stuffs, in order to learn more accurately their nutritive values.

To the former of these problems the Storrs Station is addressing a not inconsiderable part of its attention. Fortunately the United States Department of Agriculture is promoting the same inquiry. The respiration and bomb calorimeters, to which reference has been made on another page of the present Report, represent efforts in this direction.

* See Report of the Storrs Experiment Station for 1891, pp. 160 and 161, and Bulletin No. 21 of the U. S. Department of Agriculture on "Methods and Results of Investigations on the Chemistry and Economy of Food," pp. 200-213.

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